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WORLD PETROLEUM

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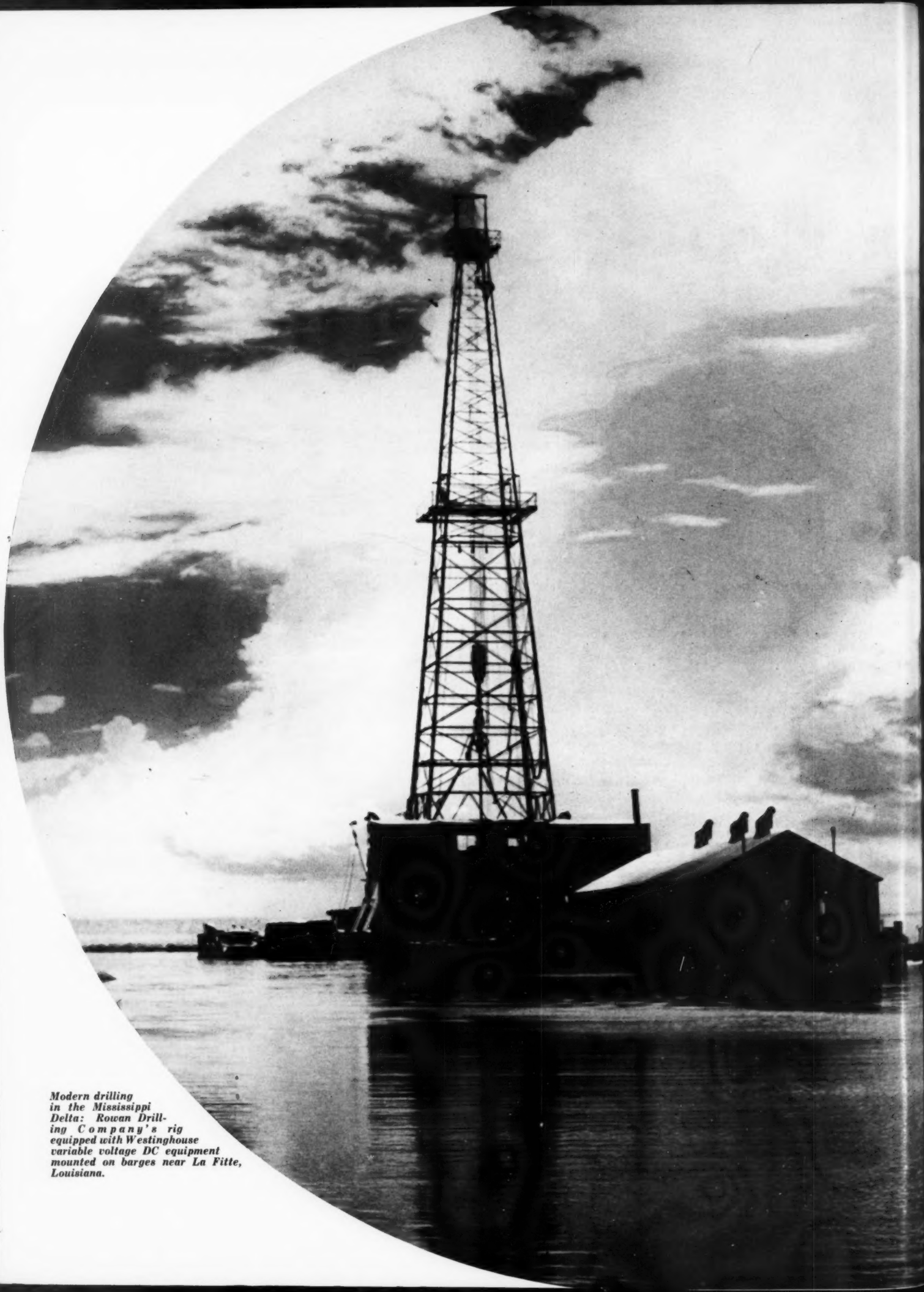

Modern drilling in the Mississippi Delta: Rowan Drilling Company's rig equipped with Westinghouse variable voltage DC equipment mounted on barges near La Fitte, Louisiana.

EDITORIAL

PRODUCTION PROBLEMS REQUIRE UNIFIED CONTROL

Within the past two months American industry has become increasingly concerned, and with reason, over the prospect of growing difficulties in obtaining materials and equipment for its essential operations. This applies both to activities closely related to the defense program and to the great body of business upon which the smooth functioning of the whole national economy depends. The chief causes for this alarming and unnecessary situation appear to be three. First is the overlapping and sometimes conflicting demands resulting from the uncoordinated issuance of priorities. Second are arbitrary efforts to cut ordinary commercial production without determining the effect of such action upon the country's ability to support the defense effort. Third, and most important because it is primarily responsible for the other two, is the failure to treat the problem of production as a whole instead of in piecemeal.

Because of the seriousness of the tangle resulting from too many loose ends there is reason to believe that decisive action to correct it will be taken soon. Even high authority must be convinced that effective coordination cannot be obtained by the multiplication of independently functioning bureaus but must come from setting up an organization for national production similar to that which has been successful in directing the country's great corporations. The task involved is nowise different in kind but only in the scale and extent of the activities involved.

American industry is not over extended. Only a fortnight ago the representatives of small establishments, which of course greatly outnumber those of large size, reported that their facilities were not fully employed, either in defense activities for which they were equipped or in ordinary commercial work where they faced indefinite delay in obtaining needed supplies. Actual shortages are few but apparent shortages are created by tying up too much material and productive equipment against needs that will be met by the steady expansion of manufacturing facilities. Too free use of preference ratings, causing plant jams, make priorities ineffective.

Vast expansion of the defense program has called for extensive readjustments to meet new conditions. The oil industry provides an illustration of the problems inherent in the necessary transition. It has been the boast of the industry that it was prepared to meet any demand that the nation's defense need might put upon it. That was no idle claim. The industry had the facilities for producing, refining and transporting all the petroleum products required by the military, naval and civil establishments of the country. When, however, a quarter of its transport fleet was transferred to the British supply service with the prospect that half the remainder might be diverted to the same employment maintenance of adequate Atlantic Coast supplies assumed an entirely different aspect.

Prompt steps to fill the deficit have been taken. Among these have been plans for the construction of more tankers, the larger use of barges and tank cars and the building of pipelines. But pipelines involve more than pipe. They require engines and pumps that are hard to supply when manufacturing plants are crowded to capacity. Barges are of little use without tow boats and here another bottleneck is encountered in the scarcity of tugs caused by the Navy's heavy demands. What began as a transportation problem threatens to handicap expansion of refining capacity and even to extend back to the field of production, with a slowing down of the all important work of exploratory drilling.

All these difficulties are receiving the careful study of experienced and competent members of the oil industry supported by the cooperation of the officials charged with the coordination of petroleum activities. The vital importance of keeping the oil industry supplied with needed tools and operating at full efficiency is not being overlooked. Obstacles that stand in the way will be overcome. The accomplishment of this result will be hastened by unified support of the measures put forward to meet the requirements of the intervening period.

Petroleum Coordinator's Organization Named: First Steps In Untangling Priorities

FINAL enactment by Congress on July 22 of the Cole pipeline bill, enabling the right of eminent domain to be exercised for the construction of lines essential to national defense, cleared the way for Petroleum Coordinator Ickes to issue immediately recommendations which had previously been decided upon covering one transcontinental crude line.

As outlined in the announcement from the Coordinator's office a 20-inch line will extend from East Texas to a point in Illinois east of St. Louis in the vicinity of Nashville, Ill., which will be known as St. Louis Junction. This line, which will extend across Arkansas and southeastern Missouri, will cross the Mississippi somewhere above Cairo, Ill. It will have a capacity of 200,000 bbl. daily. A second line of 16-inch diameter and a daily capacity of 115,000 bbl. will originate at WoodRiver, Ill., where it will take oil delivered by existing lines from the Mid-Continent and join the line from Texas at St. Louis Junction. From that point a 24-inch line carrying 250,000 bbl. will extend across Illinois, Indiana, Ohio and Pennsylvania, terminating in two outlets to serve the New York and Philadelphia refining areas.

"So routed," the Coordinator said, "the main line, with necessary feeder connection, will reach the principal sources of oil production east of the Rocky mountains, and thus will be supported with a maximum of crude reserves." He explained that the purpose of providing a capacity of 315,000 bbl. for the two supplying lines against requirements of 250,000 bbl. for the main line was to obtain greater flexibility in procuring crude oil for transportation to the East Coast.

The companies named by Mr. Ickes as having expressed their readiness to participate in construction of a line along the route indicated were Socony-Vacuum Oil Co., Standard Oil Company of New Jersey, Cities Service Co., Consolidated Oil Co., Atlantic Refining Co., Gulf Oil Co., Shell Oil Co., Tide Water Associated Oil Co., and The Texas Company. Secretary Ickes indicated that adoption of the route indicated, reached after numerous conferences with representatives of the interested companies, amounted to a compromise designed in his words, "to meet the necessities of the emergency situation with respect to the transportation of petroleum to the Atlantic Coast."

Two other recommendations advanced by Secretary Ickes and recommended to the oil companies were:

1. Immediate construction by the oil industry of 40 to 50 large, high-speed tankers in addition to the 139 now under construction. Presumably they would be designed to replace a comparable number soon to be diverted to the British supply service in addition to the 50 previously transferred largely from the Atlantic Gulf fleet.

2. That the oil industry give consideration to the question of supplementing the crude lines

Robert E. Allen, head of the division of production, office of coordinator of petroleum

with a products line from East Texas area to the Atlantic seaboard. This project was mentioned in the report of the fact finding committee of the American Petroleum Institute and submitted to Mr. Ickes June 2. It called for a 20-inch line of a daily capacity of 225,000 bbl. at an estimated cost of $70,000,000.

In announcing the definite recommendation for the route and type of the crude lines Mr. Ickes explained that he was prepared "to recommend priorities for steel and machinery" in so far as priorities in the present state of competition among even the most favored government agencies, both military and civilian, may mean anything. Further, Mr. Ickes said that it probably would take a minimum of eight months to complete the crude line even if conditions for its construction are ideal.

"Accordingly it will not be a factor in abating for some time the East Coast deficit which reached 250,000 bbl. late in July," he warned.

Approval of the transcontinental crude pipeline which is esimated to cost around $70,000,000 now places the project in the hands of the participating companies. While a number of preliminary surveys have been made the precise route to be followed by the line is still to be laid down by the engineering committee in charge and many details as to the equipment of the line remain to be decided.

Delay in enactment of the Cole bill by Congress was caused by the action of the Senate in imposing a June 30, 1943 expiration date on the authority of the President to relieve the cooperating oil companies from "any duty or liability" to which they might be subjected under the Interstate Commerce and Natural Gas Acts.

In a letter to the Senate conference committee Mr. Ickes gave formal assurance that the original objection of the Interstate Commerce Commission which prompted the Senate to write in the expiration date to this phase of the legislation, had been withdrawn. After conference with the Interstate Commission Mr. Ickes said he was able to report:

"It has been definitely agreed that the policy of the Petroleum Coordinator, to such extent as he may be involved in the administration of the pipeline legislation, will be to consult with the Interstate Commerce Commission with regard to relief from the Interstate Commerce Act and its amendments and supplements before any proclamation for such relief is recommended to the President.

"The purpose of this consultation is to make certain that persons affected by such proclamation will conform as fully as possible to regulations of the Interstate Commerce Commission, and the granting of relief therefrom is understood by and agreeable to the Interstate Commerce Commission."

The law as it now stands permits the exercise of the right of eminent domain to obtain the right-of-way for the lines and authorizes the government either to build the line directly or lend money for such construction. But before the federal government functions directly it is expressly provided that such action shall be taken only in the event "it is impracticable for any private person promptly and satisfactorily to undertake construction, extension or completion." In effect the law waives the operation of the anti-trust act by permitting the oil companies to

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W. W. Gary, chairman of the division of refining.

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H. A. Gilbert, chairman of the division of transportation.

cooperate in an undertaking as well as the regulations of the Interstate Commerce Commission and the Natural Gas Act in the manner outlined by Mr. Ickes.

Subsequently Coordinator Ickes and Deputy Coordinator Ralph K. Davies held two conferences with oil and shipping men, the first shrouded in secrecy and concerned with the new tanker demands by the British Service of Supply. In the second Mr. Davies outlined to representatives of companies doing business in South America the policy decreed by the State Department "to do nothing to abate the East Coast shortage that will require Latin American countries to carry a greater burden than we do." Following the meeting called at the instance of Nelson Rockefeller, of the Office of Coordination of Commercial and Cultural Relations between the American Republics, it was indicated, the Latin American countries will be expected to take a cut in oil imports equal to the curtailment of tanker shipments to the East Coast of the United States.

Mr. Davies was as uncommunicative as Mr. Ickes had been on the "reallocation" of tankers. Following the conference with the oil and shipping men on the latest request for diversion of additional tanker tonnage to the British supply service Mr. Ickes issued a formal statement:

"The transfer of oil tankers, or proposals for their transfer or reallocation and diversion of tankers, are matters of vital military information. Accordingly, the Office of the Petroleum Coordinator cannot, at this time, comment on any discussions, proposals, or action taken at the meeting held today.

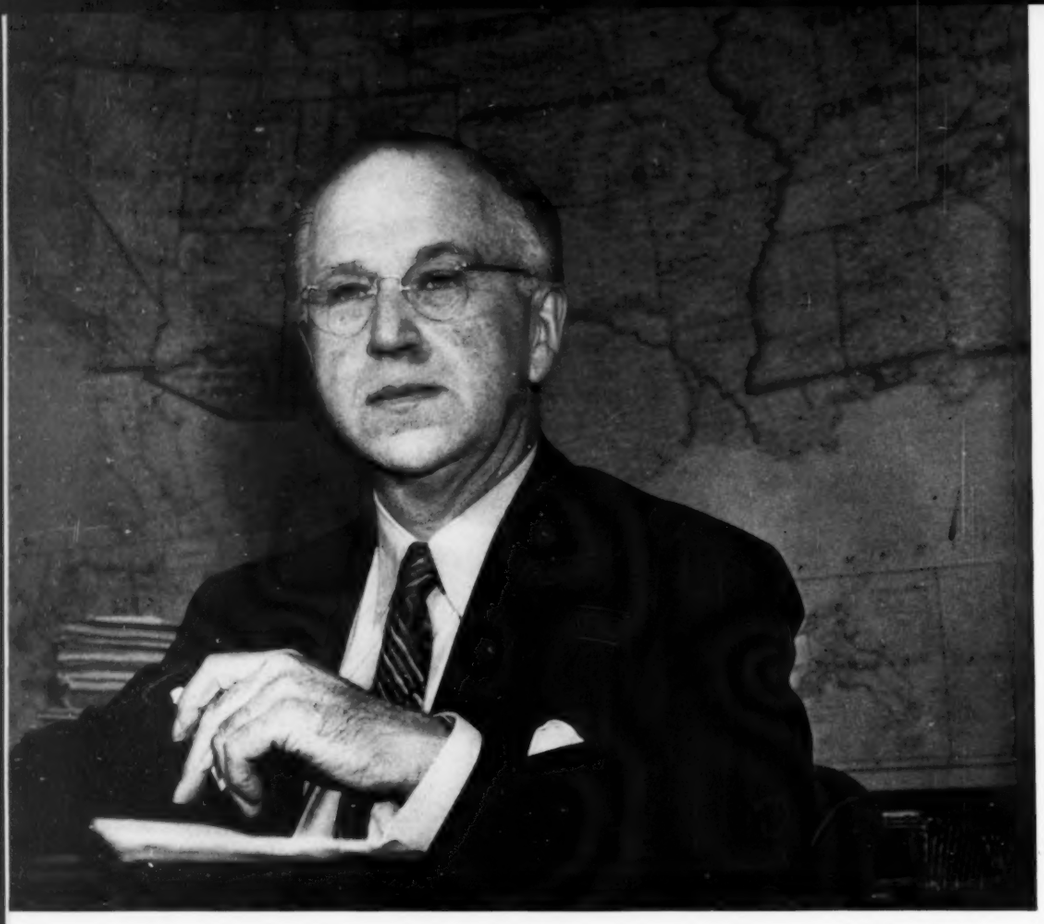
"I believe the American press generally will recognize that this particular subject is one which is of vital importance to our national defense and, realizing that, will refrain from publishing such information in so far as it involves specifics."

In informed quarters it was indicated the British requested 10 tankers a month which gave rise to reports that they wanted 100 more. From the same source it was learned that not more than 30 would be spared at the present time with additional tonnage probably diverted on a monthly basis as ship construction permitted.

Coordinator Ickes has named to his general staff four experts on production, refining, transportation and marketing, to head these four divisions of the industry under Deputy Coordinator Davies and to work with industry committees now organized in the five regional districts into which the country has been divided. Branch offices will be established in New York, Chicago, Denver, Houston and Los Angeles. These heads of divisions are Robert E. Allen for production: W. W. Gary, refining; H. A. Gilbert, transportation, John W. Frey, marketing; H. A. Yocom director of information. E. De Golyer heads the conservation section while E. B. Swanson is in charge of research and statistics and S. W. Crosthwaite, W. S. Arnold are administrative assistants. George W. Holland is a special assistant and S. Howard Marshall is chief counsel.

The Coordinator's office has asked for voluntary cooperation by the industry and the consumers of motor fuel to reduce consumption 33⅓ percent in the Atlantic coast states which it is now estimated is essential if rationing of available supplies in the last quarter of 1941 is to be avoided. The recommendation which has been communicated to the governors of the sixteen affected states has been supplemented by a request to nineteen large oil companies operating in the area to report weekly on their retail sales. The telegram signed by Deputy Coordinator Davies said:

"For the purpose of measuring what effect requests for voluntary curtailment have on the consumption of gasoline in the so called East Coast refining district will you please report in one total



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Dr. John W. Frey, chairman of the division of marketing.

E. De Golyer, head of the conservation section.

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S. W. Crosthwaite, administrative assistant in the petroleum coordinator's organization.

figure for the week ending Friday the 18th of July and for each week ended Friday until further notice your net sales of motor fuel (gasoline) to dealers and through your own service stations to consumers. We do not want sales to jobbing resellers nor to large tank car buyers or commercial accounts since these do not entirely reflect reaction of private owners, nor are we trying to develop figures indicating total district sales. What we do want to develop is the nearest possible measure of the trend of retail purchasing in this area and what effect requests for voluntary curtailment have on the use of gasoline. Obviously shipments from refineries and terminals to points of consumption will not suffice."

Supporting the Coordinator's appeal for public cooperation in saving gasoline the industry's marketing committee for the first district, which includes the Atlantic Coast states, has undertaken the use of newspaper advertising space pointing out specific steps to conserve motor fuel.

Based on nominations invited from members of all branches of the oil industry the Coordinator has designated five committees in each of the five districts into which the country has been divided. The duties of these committees are "to advise and consult with" the Coordinator and Deputy Coordinator on matters relating to the activities of the petroleum industry in the various regions in which the committees are located, and "to assist in the performances of such specific recommendations or instructions as may be issued." In each district a committee of ten is designated for each division of the industry, that is for production, refining, transportation and marketing.

District No. 1: New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia and Florida. General Committee: John A. Brown, chairman, Socony-Vacuum Oil Co.; Walter S. Hallaman, Plymouth Oil Co.; R. H. Colley, Atlantic Refining

J. Elmer Thomas who has recently joined the Office of Price Administration and Civilian Supply.

Co.; W. A. Jones, Cities Service Co.; H. W. Dodge, The Texas Corporation.

District No. 2: Ohio, Kentucky, Tennessee, Indiana, Michigan, Illinois, Wisconsin, Minnesota, Iowa, Missouri, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota. General Committee: Frank Phillips, chairman, Phillips Petroleum Co.; O. D. Donnell, Ohio Oil Co.; Paul G. Blazer, Ashland Oil and Refining Co.; E. G. Seubert, Standard Oil Co. (Indiana); B. L. Majewski, Deep Rock Oil Co.

District No. 3: Alabama, Mississippi, Louisiana, Arkansas, Texas and New Mexico, General Committee: Charles F. Roeser, chairman, Roeser and Pendleton; George A. Hill, Houston Oil Co.; John W. Newton, Magnolia Oil Co.; H. C. Wiess, Humble Oil and Refining Co.; Roy B. Jones, Panhandle Producing and Refining Co.

District No. 4: Montana, Wyoming, Colorado, Utah and Idaho. General Committee: W. H. Ferguson, chairman, Continental Oil Co.; R. S. Shannon, Minnelusa Oil Co.; Henry Molye, Wasatch Oil and Refining Co.; Burton W. Musser, Utah Oil Refining Co.; H. Earl Clack, Clack Oil Co.

District No. 5: Arizona, California, Nevada, Oregon and Washington. General Committee: A. L. Weil, chairman; E. E. Pyles, Hancock Oil Co.; W. L. Stewart, Jr., Union Oil Co.; C. S. Jones, Richfield Oil Co.; C. S. Beesemyer, Gilmore Oil Co.

As the result of recent disclosures in Congress that Navy shipbuilding was not getting the highest priorities in some cases, together with differences between O.P.M. Director William Knudsen and Price Administrator Leon Henderson over the extent of reduction to be made in the automobile output, a complete revamping of the present priorities set-up appears likely. Recent difficulties experienced by the Portland Pipe Line Company in getting material for the construction of line between Portland, Me. and Montreal is being inquired into by the Coordinator's office, as an indication of the situation applying to many important projects.

In an effort to simplify the method by which priorities have been handled, Director E. R. Stettinius has initiated a new plan for granting limited blanket preference ratings for important defense projects. The new blanket rating will be carefully restricted.

It is the belief that the new system will eliminate most of the routine. When a project is officially selected for such treatment the supplier will be granted a preference rating which is appropriate to the need involved. The order carrying this preference rating will be, in general, similar to blanket ratings hitherto assigned to the builders of freight cars, merchant ships, and the producers of machine tools.

Fraser Heads Anglo-Iranian

Sir William Fraser, Kt., has been made Chairman of the Anglo-Iranian Oil Co., Ltd., succeeding the late Lord Cadman of Silverdale. Mr. Fraser has been connected with the company for many years. Since 1928, when be became Deputy Chairman, the administration of the widely scattered operations of the company has passed into his hands in steadily increasing degree.

Born at Glasgow in 1888, Mr. Fraser was educated at Glasgow Academy and the Royal Technical College. His early business activities were in association with the Scottish shale oil industry. He became a director of Pumpherston Oil Company in 1913 and was made joint managing director two years later. During the first world war he devoted much time to oil productio in the United Kingdom and in 1918 he was awarded C. B. E. for public servives. In that same year he was sent to the United States as chairman of the specifications committee appointed by the Inter-Allied Petroleum Council to coordinate the movement of petroleum supplies for the Allies.

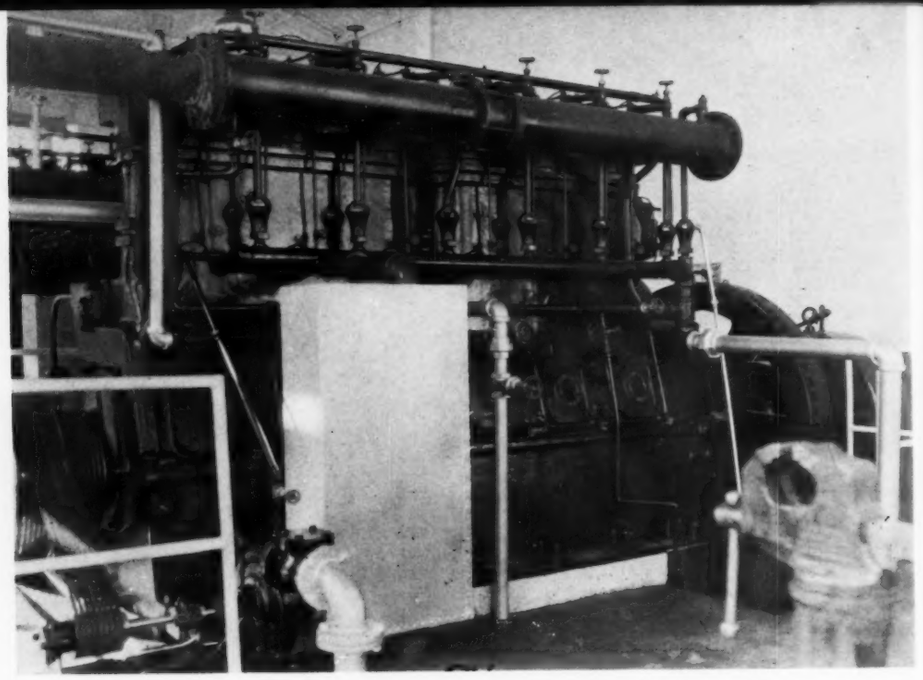
Following the war Mr. Fraser established a joint selling agency for the shale oil interests and in 1919 he organized Scottish Oils Ltd. to combine the producing and marketing interests of the shale oil industry with the Anglo-Iranian (then Anglo-Persian) Company. In 1923 he became a director of Anglo-Iranian and five years later was made Deputy Chairman and in that position took an active part in the formation of Shell Mex and B. P., the well known British marketing organization.

In 1932 Mr. Fraser was one of the British representatives at the international oil conference held in New York and in 1933 he accompanied Lord Cadman on his mission to Teheran to negotiate a revised concession for the company.

As a director of Iraq Petroleum Company Mr. Fraser has played an important part in the development of Iraq oilfields, especially in the formation of Consolidated Refineries and the construction of the refinery at Haifa. In addition to the positions mentioned Mr. Fraser has been a director of the Burmah Oil Co., Anglo-Egyptian Oilfields, Steua-Romana (British) and Kuwait Oil Co. At the beginning of the present war he became a member of the Petroleum Board which has charge of oil supplies for Britain.

Mr. Fraser was married in 1913 to Mary McLintock. They have one son and one daughter.

SELECTION DATA FOR DIESEL PIPELINE PUMPING ENGINES



One of 19 Chicago Pneumatic engines on the Phillips gasoline line rated at 270 h.p. at 360 r p m. driving a centrifugal pump through Westinghouse step up gears.

By Edgar J. Kates

Consulting Engineer

New York

THE accompanying tables (page 30-31) were prepared for the purpose of assisting engineers of pipeline companies who wish to purchase heavy-duty American-built Diesel engines of 200 to 1000 h.p. capacity for driving mainline pumps. This has become an urgent matter because the diversion of large numbers of oil tankers to the British in the interest of National Defense has materially depleted transportation facilities on the Atlantic seaboard. Furthermore, pipelines have a strategic advantage which is important in these days when military considerations are dominant; they are relatively immune to enemy action as compared to exposed tankers. For these reasons, in addition to economic ones, new pipelines are being built and projected, and the capacity of existing lines is to be increased by building booster stations. Whether new lines are built or old ones stepped up, large numbers of new engines will be needed and they will not be as easy to obtain as heretofore.

Many engine-building factories are blocked with unfilled orders for the Army and Navy, and it is therefore advisable for pipeline engineers to know the various makes and types available in order that they may have the widest possible latitude of choice. These tables are intended to facilitate the preliminary selection of such engines.

There are two tables, Table 1 being the "finding table", where all of the engines are listed in order of horsepowers. In this respect the arrangement differs from previously published tabulations in which engines are grouped under manufacturers' names and further classified, if classified at all, merely by high-speed, medium-speed and low-speed designations. Table 1 identifies each engine, presents a few details, and then shows a cross-reference to Table 2 which gives further engine details in compact and readily usable form for ready reference.

The foregoing arrangement was adopted because the basic data on which a pipeline engineer works are the size and length of line between pumping stations, the relative elevations, the kind of oil to be pumped and the pumping capacity desired. From these data he computes the horsepower needed for each pumping unit. Our finding table (Table 1) is therefore logically arranged in order of horsepowers.

The tables were restricted to engine rating of 200 to 1000 horsepower for the sake of simplifying the selection of engines in this size range, within which fall nearly all modern Diesel engines used for mainline pumping. Consequently the tables do not include the smaller, higher speed engines with strokes as small as eight inches and speeds up to 900 r.p.m., which have occasionally been employed.

The engine ratings, dimensions and weights listed in these tables were obtained directly from the several manufacturers, who were also given an opportunity to check the proofs. Data was solicited from all manufacturers of heavy-duty 200-1000 h.p. Diesel engines frequently used for pipeline pumping, and almost all of them responded willingly. Engine ratings as to horsepower and speed are as proposed by the manufacturers themselves for mainline pumping service.

Table 1 starts by showing, in ascending order from 200 h.p. to 1000 h.p., the rated horsepower of each of the 140 engines listed.

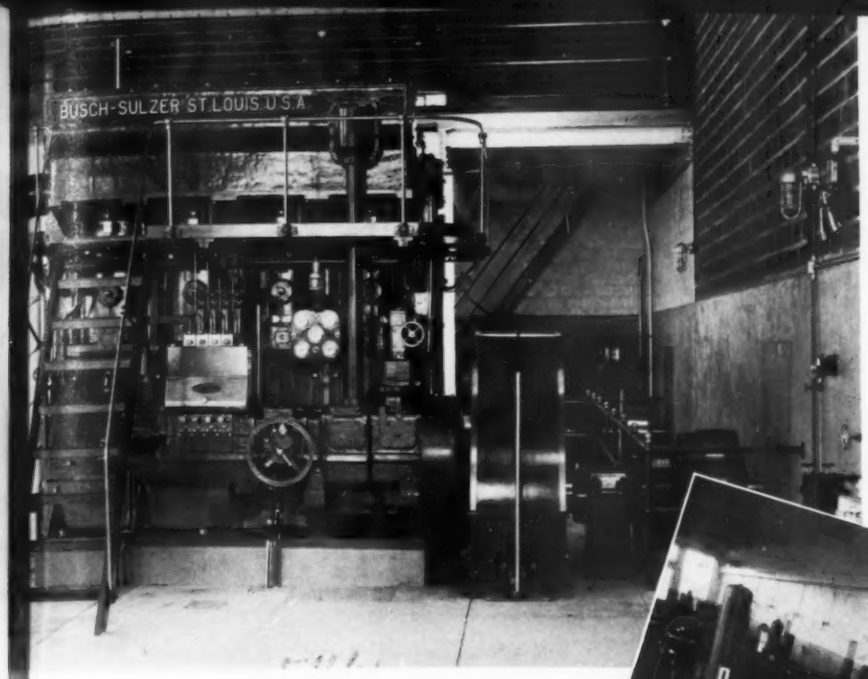
Concentrating on that part of the table showing engines of the same or nearly the same horsepower as that required, the engineer next finds, in the second column, rated speed, which at once further narrows his search by eliminating engines running at speeds which he does not consider suitable for his purpose. In this connection it is interesting to note the wide range of speeds available at a given horsepower; for instance, at 225 h.p., speeds range from 300 to 720 r.p.m.

Reading across Table 1, the engineer finds, for each engine of the desired horsepower and speed, the name of the manufacturer, the number of cylinders, the bore and stroke, and the net weight without flywheel, as well as a reference to the particular line in Table 2 where additional information may be found. Net weight without flywheel was used because it was a readily available figure which is more significant than shipping weight or net weight including flywheel, neither of which is a good measure of an engine's working weight. Wide ranges in weight for the same horsepower are evident from the table; for instance, engines of 525 h.p. rating weigh as little as 23,990 lbs. and as much as 76,100 lbs., or a ratio of 3.2:1. The lighter engine of course has a higher rotative speed, in the ratio of 2.4:1; in addition it may be seen that the lighter engine has a higher piston speed, in the ratio of 1.6:1.

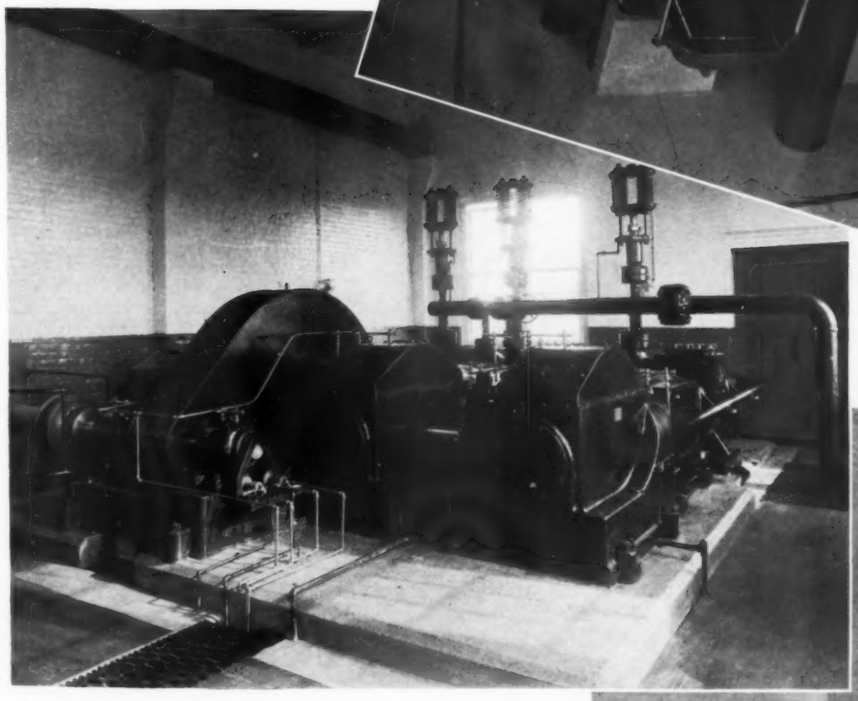
Table 2, which is tied into Table 1 by means of reference numbers, gives further engine details. The data is common to all engines of a given model and can therefore be listed here more compactly than if it were shown repetitively in Table 1. It includes model designation, four cycle or two cycle, piston speed, rated horsepower per cylinder, brake mean effective pressure (B.M.E.P.), diameters of main journals and crank journals, and ratio of the projected area of the crank bearing to the area of the piston. The computations for piston speed, B.M.E.P. and ratio of projected area of crankbearing to area of piston were made by us, based on the dimensional data and horsepower ratings furnished by the manufacturers. This information is given

for 41 models (in some cases for two different rated speeds), and when expanded by the various numbers of cylinders in each model, corresponds to the larger number of horsepower ratings in Table 1.

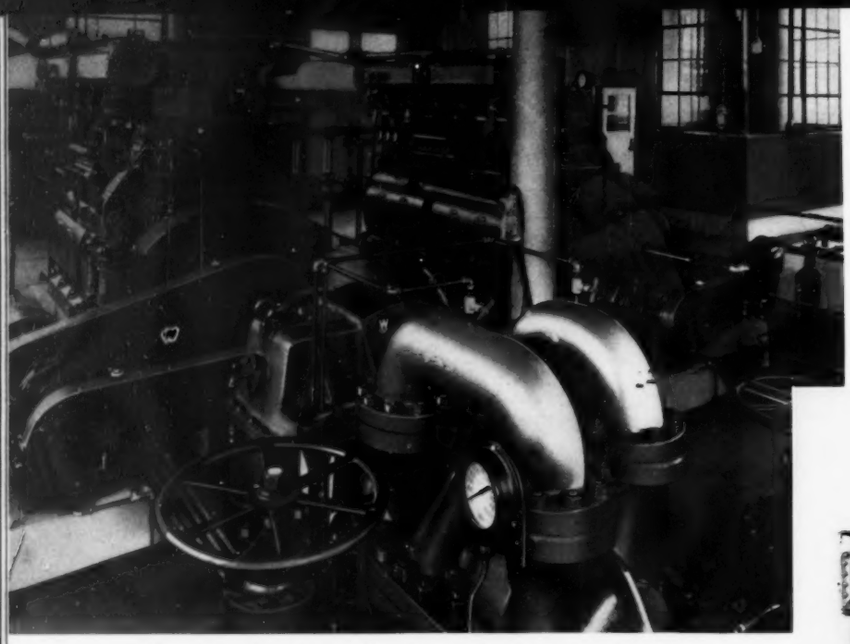
Table 2 strikingly illustrates the wide variations in design practices and rating standards of the various manufacturers, already mentioned in the comments on Table 1. It will be seen, for instance, that piston speeds of engines offered for mainline pumping range from 770 to 1440 feet per minute, or almost 2 to 1. Brake mean effective pressures for four-stroke cycle engines range

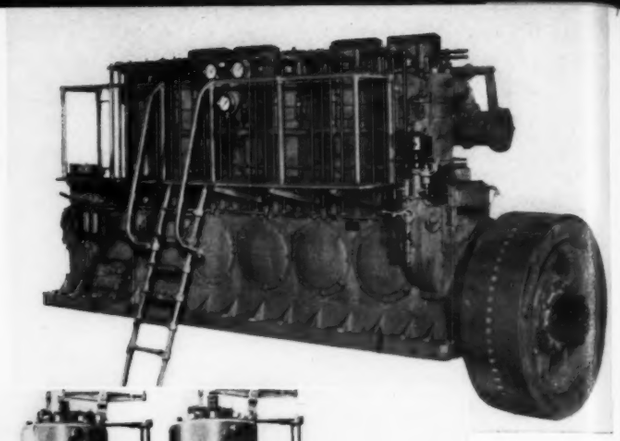


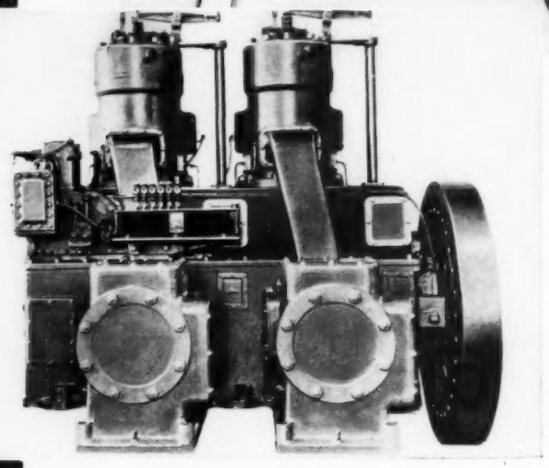
Above, a Busch-Sulzer Diesel engine installation on a pipeline at Beck, Neb. Right, Pump room at Manhattan, Ill. driven by 1000 h.p. Nordberg Diesel shown on the following page.



Above, pumps operated through Falk gear unit driven by 400 h.p. Rathbun-Jones Diesel shown at right. The pumps operate in conjunction with a bank of coils and a pond. The flow of raw water over the coils is regulated by a thermostatically controlled by-pass around the new water pump.

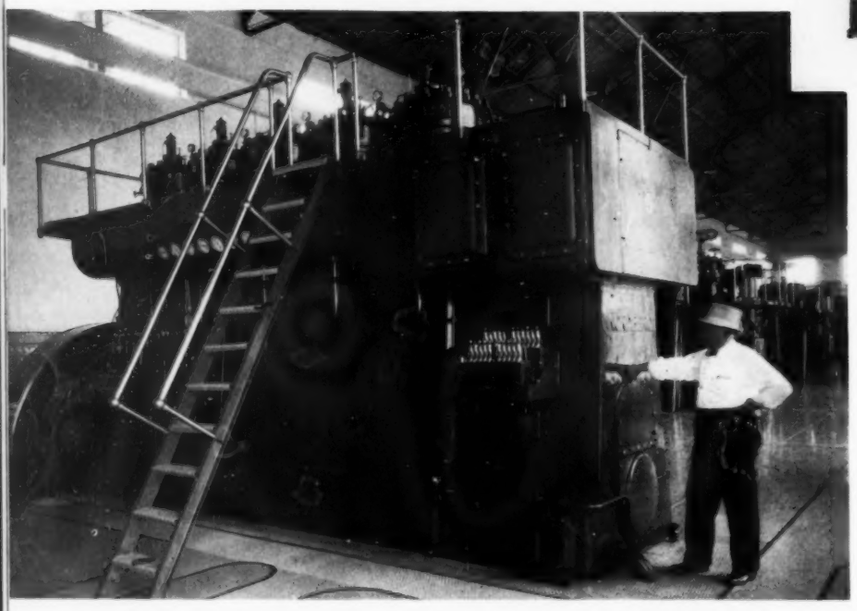




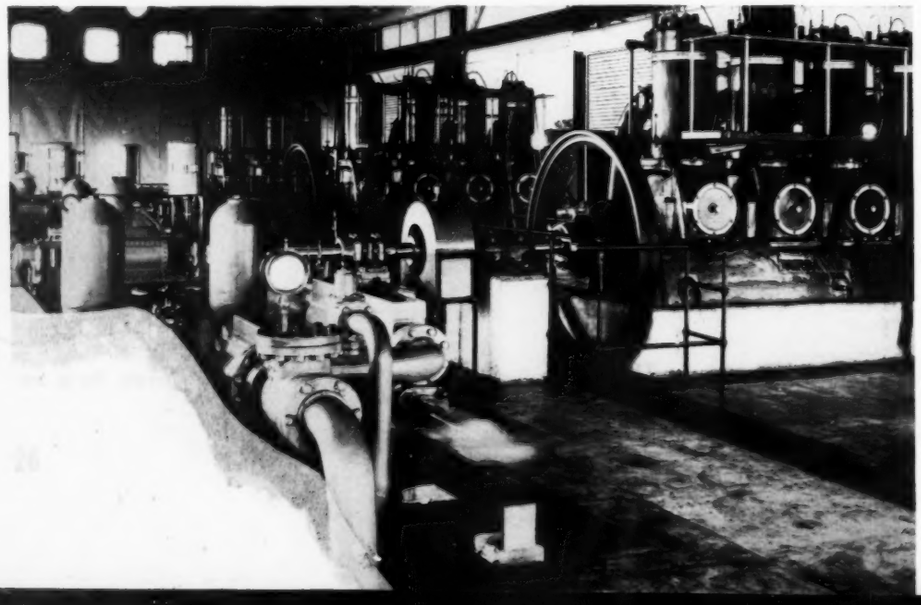


Above, American Locomotive Company Diesel engine for main line pumping service on a line operated by Magnolia Pipe Line Company. Below, 5-cylinder, 1000 h.p. Nordberg Diesel in the Manhattan, Ill. station of the Stanolind Pipeline Co.

Top above, 6-cylinder 15 by 19 Atlas Imperial Diesel developing 600 h.p. at 300 r.p.m. Directly above, a Clark Brothers 200 h.p. two cycle angle unit for pipeline service.



Below, one 3-cylinder and two 4-cylinder, 14 by 17 Fairbanks Morse engines direct connected to 24 in. duplex pumps in the Refugio, Texas station of the Atlantic Pipeline Co.



from 70 to 80 lbs. per sq. in., except for supercharged engines which go up to 112 lbs. But for two-stroke cycle engines, B.M.E.P.s range from 38 to 68 lbs. per sq. in., the lower figure naturally pertaining to those Diesel engines employing crankcase scavenging.

Piston speed is listed because it is well known that rotative speed alone is not a complete measure of the effects of engine speed. For instance, rotative speed alone does not measure the linear velocity of the reciprocating wearing surfaces, which is an important factor in the lubrication of these parts. Neither is piston speed by itself a complete criterion; obviously it does not show the number of reversals of the reciprocating parts, nor the length of time available for injecting the fuel. It is therefore necessary to consider both R.P.M. and piston speed. For this purpose many engineers have adopted the "speed characteristic" proposed by V. L. Maleev before the A.S.M.E. in 1932, which is the product of revolutions per minute and piston speed.

Some engineers like to compare engine horsepowers on a common B.M.E.P. basis such as 75 lbs. per sq. in. for four-stroke cycle engines. This can easily be done by means of the adjacent columns showing rated horsepower per cylinder and brake mean effective pressure.

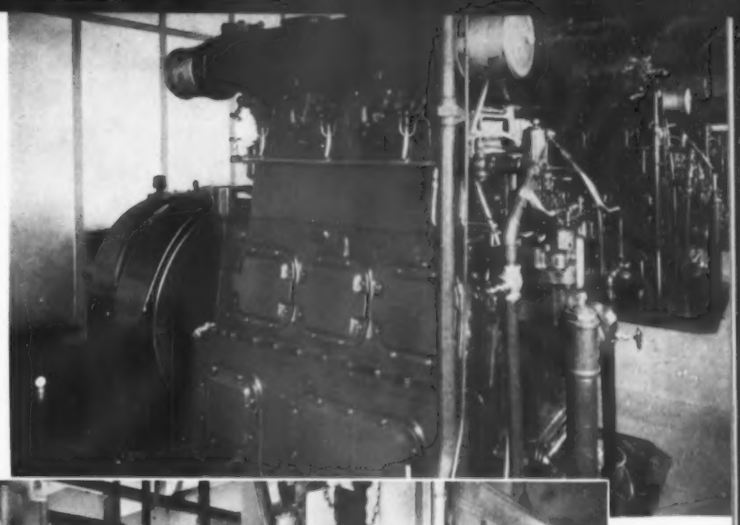
Diameters of the crankshaft journals, both at the main bearing and at the crankpin bearing, are listed for the guidance of engineers concerned

with the stiffness of the crankshaft to resist the bending moment due to the piston forces acting on the crankpins, and also its twisting strength as regards torsional vibrations. In addition, it is easy to compute from these dimensions the ratio of shaft diameter to piston diameter.

Ratio of projected area of crankbearing to area of piston was computed by dividing the product of diameter and length of crankbearing by the area of the piston. This ratio is sometimes used as a rough and ready measure of the unit pressure on the crankbearing, but since other factors such as inertia forces are involved, the ratio should be used with discretion.

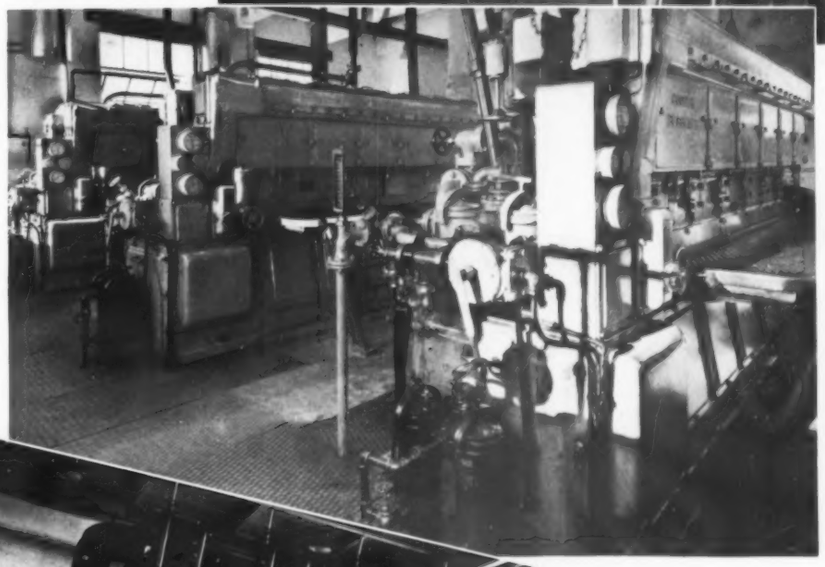
Fuel consumption guarantees have not been tabulated here because they are of little real value in estimating the comparative fuel consumptions of different makes of engines in actual service.

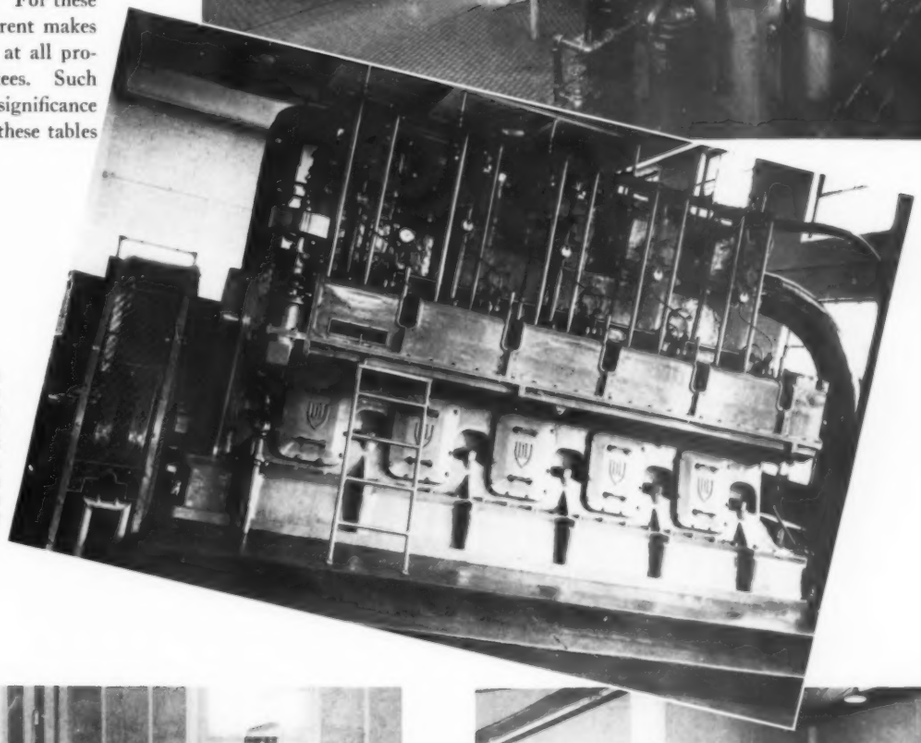
It is not implied that engines do not meet their guarantees; on the contrary, most engines are found to operate well within the guarantees. The trouble is that guarantees generally include a stated tolerance, usually five percent, and also that manufacturers' policies vary as to the allowance they make between their test floor fuel consumption and their guaranteed figures. For these reasons the fuel consumptions of different makes of engines in the field are usually not at all proportional to their respective guarantees. Such guarantees therefore would have little significance in the preliminary comparisons which these tables are intended to assist.



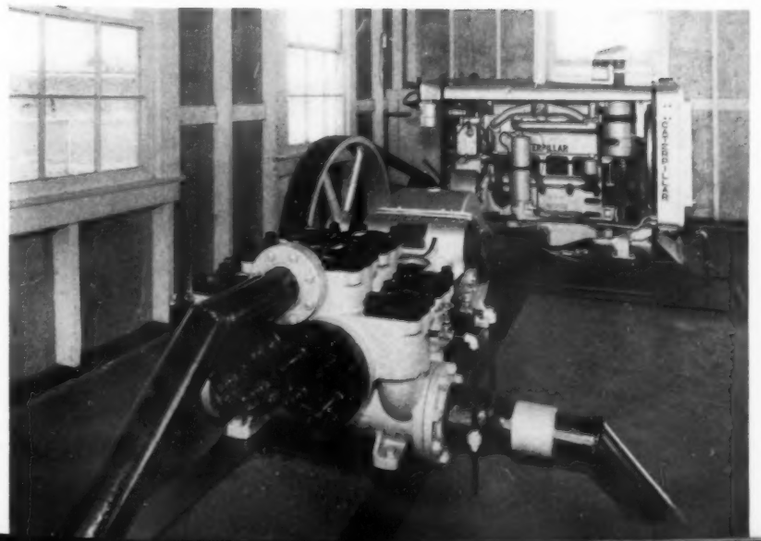
Right, five 3-cylinder Ingersoll-Rand Diesels at the Patoka, Ill. station on the Illinois Pipeline Company's main line; engines are direct connected through Falk gears to vertical triplex pumps.

Below, three Cooper-Bessemer 6-cylinder Diesels driving alternators and exciters at 400 r.p.m. furnishing power for motor driven pipeline pump stations at Mt. Enterprise, Texas.





Right, one of two 5-cylinder De La Vergne diesels on the Great Lakes Pipeline Company's main line: Below left, a light Caterpillar driving a 4 by 6 horizontal duplex pump moving 75 bbl. of crude at 640 lb. pressure: Below right, two Worthington Diesels driving centrifugal pipeline pumps through speed increasing gears on the Magnolia line in Illinois.



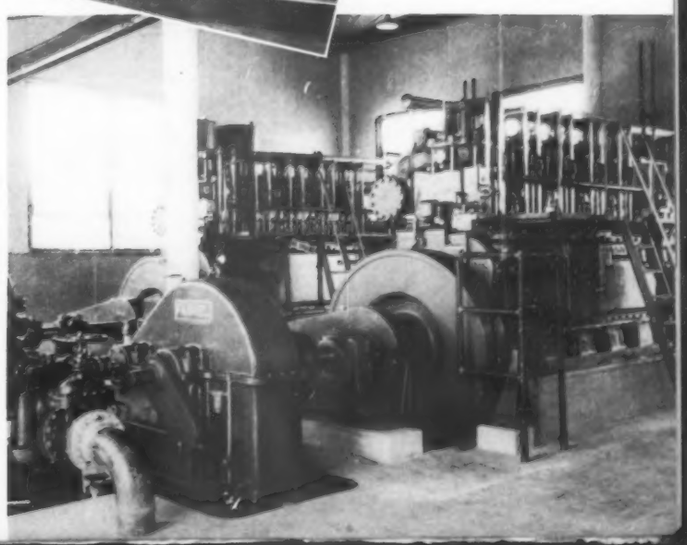


Table 1 List of Engines by Horsepower

Horse Power	RPM	ENGINE MANUFACTURER	No. of cyls.	Bore In.	Stroke In.	Net weight without flywheel lbs.	For other details see Table 2 Line No.
200	514	Atlas Imperial Diesel Engine Company	6	9	10½	14,656	11
200	327	" " " " "	4	11½	15	28,955	13
200	600	Clark Bros. Co.	4	10	12	14,820	46
200	720	" " "	3	10	12	11,570	47
200	950	Waukesha Motor Co.	6	7	8½	7,700	95
220	360	Atlas Imperial Diesel Engine Co.	6	10	13	23,800	12
225	360	Busch-Sulzer Bros.—Diesel Engine Co.	3	13	17	29,100	31
225	300	" " " " " "	3	13	20	31,300	33
225	400	Chicago Pneumatic Tool Co.	4	10¾	14¼	21,800	42
225	514	Cooper Bessemer Corp.	6	9	12	15,000	52
225	300	Fairbanks, Morse & Co.	3	14	17	26,160	61
225	720	Ingersoll-Rand Co.	3	10½	12	11,790	71
225	360	Rathbun-Jones Engineering Co.	4	11	18	24,000	91
225	450	Worthington Pump & Machinery Corp.	4	10¾	14½	20,100	101
230	400	Baldwin De La Vergne Sales Corp.	3	12¾	15½	17,000	21
250	400	Busch-Sulzer Bros.—Diesel Engine Co.	3	13	17	29,100	32
250	327	" " " " " "	3	13	20	31,300	34
250	360	Worthington Pump & Machinery Corp.	3	13¼	17½	28,850	102
255	600	Cooper Bessemer Corp.	8	8	10½	14,500	51
260	330	Clark Bros. Co.	3	13	14	29,250	48
260	300	Rathbun Jones Engineering Co.	3	13¼	22	27,000	92
265	327	Atlas Imperial Diesel Engine Co.	4	13	16	34,000	14
265	720	Clark Bros. Co.	4	10	12	14,820	47
275	514	Atlas Imperial Diesel Engine Co.	8	9	10½	18,730	11
280	900	Waukesha Motor Co.	6	8½	8½	9,000	96
280	450	Worthington Pump & Machinery Corp.	5	10¾	14½	22,525	101
280	400	Chicago Pneumatic Tool Co.	5	10¼	14¼	24,700	43
285	750	" " " "	6	8	10½	15,500	38
285	720	" " " "	6	9	10½	15,600	40
294	360	Rathbun Jones Engineering Co.	5	11	18	28,000	91
300	327	Atlas Imperial Diesel Engine Co.	6	11½	15	36,000	13
300	300	Busch Sulzer Bros. Diesel Engine Co.	4	13	20	38,800	33
300	360	" " " " " "	4	13	17	35,900	31
300	600	Clark Bros. Co.	6	10	12	21,320	46
300	300	Fairbanks-Morse & Co.	4	14	17	31,710	62
300	720	Ingersoll Rand Co.	4	10½	12	14,770	71
310	400	Baldwin De La Vergne Sales Corp.	4	12¾	15½	20,000	21
310	514	Cooper Bessemer Corp.	8	9	12	18,500	52
320	450	" " "	6	10½	13½	25,000	53
330	360	Worthington Pump & Machinery Corp.	4	13¼	17½	33,800	102
333	327	Busch Sulzer Bros. Diesel Engine Co.	4	13	20	38,800	34
333	400	" " " " " "	4	13	17	35,900	32
335	400	Chicago Pneumatic Tool Co.	6	10¾	14¼	27,800	44
340	450	Worthington Pump & Machinery Corp.	6	10¾	14½	28,100	101
347	300	Rathbun-Jones Engineering Co.	4	13¼	22	36,000	92
350	330	Clark Bros. Co.	4	13	14	39,380	48
350	360	Rathbun Jones Engineering Co.	6	11	18	34,000	91
375	300	Busch Sulzer Bros. Diesel Engine Co.	5	13	20	46,300	33
375	360	" " " " " "	5	13	17	42,700	31
375	300	Fairbanks, Morse & Co.	5	14	17	38,460	62
375	720	Ingersoll-Rand Co.	5	10½	12	17,600	71
375	327	Worthington Pump & Machinery Corp.	3	16	20	39,100	103
380	750	Chicago Pneumatic Tool Co.	8	8	10½	19,400	39
380	720	" " " "	8	9	10½	19,500	41
380	327	Baldwin De La Vergne Sales Corp.	4	15	18½	44,000	22
380	277	Rathbun Jones Engineering Co.	3	16	24	38,000	93
390	400	Baldwin De La Vergne Sales Corp.	5	12¾	15½	24,000	21
395	450	Worthington Pump & Machinery Corp.	7	10¾	14½	32,525	101
400	327	Atlas Imperial Diesel Engine Co.	6	13	16	50,100	14
400	600	Clark Bros. Co.	8	10	12	27,820	46
400	720	Clark Bros. Co.	6	10	12	21,320	47
408	360	Rathbun Jones Engineering Co.	7	11	18	40,000	91
415	360	Worthington Pump & Machinery Corp.	5	13¼	17½	40,250	102
416	327	Busch Sulzer Bros. Diesel Engine Co.	5	13	20	46,300	34
416	400	" " " " " "	5	13	17	42,700	32
425	450	Cooper-Bessemer Corp.	8	10½	13½	34,000	53
430	400	" " "	5	13	16	38,400	54
435	330	Clark Bros. Company	5	13	14	48,275	48
440	300	Rathbun Jones Engineering Co.	5	13¼	22	44,000	92
450	360	Busch Sulzer Bros. Diesel Engine Co.	6	13	17	49,500	31
450	300	" " " " " "	6	13	20	53,800	33
450	400	Chicago Pneumatic Tool Co.	8	10¾	14¼	33,400	45
450	300	Fairbanks Morse & Co.	6	14	17	45,900	62
450	720	Ingersoll-Rand Co.	6	10½	12	21,090	71
450	450	Worthington Pump & Machinery Corp.	8	10¾	14½	36,950	101
465	400	Baldwin De La Vergne Sales Corp.	6	12¾	15½	28,000	21
465	360	Rathbun Jones Engineering Co.	8	11	18	44,500	91
475	327	Baldwin De La Vergne Sales Corp.	5	15	18½	53,000	22
500	400	Busch Sulzer Bros. Diesel Engine Co.	6	13	17	49,500	32
500	327	" " " " " "	6	13	20	53,800	34
500	300	" " " " " "	4	16½	21	64,100	35
500	257	" " " " " "	4	16½	24½	70,400	37
500	400	Fairbanks, Morse & Co.	5	12	15	47,165	63
500	327	Worthington Pump & Machinery Corp.	4	16	20	50,800	103
500	360	" " " "	6	13¼	17½	47,100	102
506	277	Rathbun Jones Engineering Co.	4	16	24	53,000	93
510	300	" " " "	6	13¼	22	54,000	92
525	300	Atlas Imperial Diesel Engine Co.	6	14½	18	76,100	15
525	300	Busch Sulzer Bros. Diesel Engine Co.	7	13	20	61,300	33
525	360	" " " " " "	7	13	17	56,300	31
525	330	Clark Bros. Company	6	13	14	54,400	48
525	400	Cooper Bessemer Corp.	6	13	16	43,600	54
525	720	Ingersoll-Rand Company	7	10½	12	23,990	71
535	720	Clark Bros. Company	8	10	12	27,820	47
540	600	(Alco) American Locomotive Co., Non Supercharged	6	12½	13	39,100	1
545	400	Baldwin De La Vergne Sales Corp.	7	12¾	15½	32,000	21
545	327	Busch Sulzer Bros. Diesel Engine Co.	4	16½	21	64,100	36
570	327	Baldwin De La Vergne Sales Corp.	6	15	18½	62,000	22
575	300	Fairbanks Morse & Co.	5	14	17	59,592	64
580	360	Worthington Pump & Machinery Corp.	7	13¼	17½	52,900	102
582	300	Rathbun Jones Engineering Co.	7	13¼	22	64,000	92
583	327	Busch Sulzer Bros. Diesel Engine Co.	7	13	20	61,300	34
583	400	" " " " " "	7	13	17	56,300	32
600	300	Atlas Imperial Diesel Engine Co.	6	15	19	77,200	16
600	360	Busch Sulzer Bros. Diesel Engine Co.	8	13	17	63,200	31
600	300	" " " " " "	8	13	20	68,800	33
600	490	Cooper Bessemer Corp.	7	13	16	49,600	54
600	430	Fairbanks Morse & Co.	6	12	15	51,165	63

Horse Power	RPM	ENGINE MANUFACTURER	No. of cyls.	Bore In.	Stroke In.	Net weight without flywheel lbs.	For other details see Table 2 Line No.
600	720	Ingersoll-Rand Co.	8	10½	12	27,575	71
620	400	Baldwin De La Vergne Sales Corporation	8	12¾	15½	36,000	21
625	257	Busch Sulzer Bros. Diesel Engine Co.	5	16½	24½	84,000	37
625	300	" " " " " "	5	16½	21	76,500	35
625	300	Cooper Bessemer Corp.	5	15½	22	67,000	55
625	327	Worthington Pump & Machinery Corp.	5	16	20	61,300	103
634	277	Rathbun Jones Engineering Co.	5	16	24	67,000	93
665	327	Baldwin De La Vergne Sales Corp.	7	15	18½	71,000	22
665	360	Worthington Pump & Machinery Corp.	8	13¼	17½	58,650	102
666	400	Busch Sulzer Bros. Diesel Engine Co.	8	13	17	63,200	32
666	327	" " " " " "	8	13	20	68,800	34
675	400	Cooper Bessemer Corp.	8	13	16	55,600	54
681	327	Busch Sulzer Bros. Diesel Engine Co.	5	16½	21	76,500	36
690	300	Fairbanks Morse & Co.	6	14	17	67,392	64
694	300	Rathbun Jones Engineering Co.	8	13¼	22	73,000	92
700	330	Clark Bros. Co.	8	13	14	62,400	49
700	300	Fairbanks Morse & Co.	4	16	20	70,580	65
700	400	" " "	7	12	15	55,165	63
750	327	Baldwin De La Vergne Sales Corp.	6	16	20	70,000	23
750	300	Busch Sulzer Bros. Diesel Engine Co.	6	16½	21	88,900	35
750	257	" " " " " "	6	16½	24½	97,700	37
750	300	Cooper Bessemer Corp.	6	15½	22	79,000	55
750	300	Nordberg Mfg. Co.	6	16	22	85,000	81
750	257	" " "	3	17	25	89,000	82
750	327	Worthington Pump & Machinery Corp.	6	16	20	72,500	103
760	327	Baldwin De La Vergne Sales Corp.	8	15	18½	80,000	22
760	277	Rathbun Jones Engineering Co.	6	16	24	81,000	93
805	300	Fairbanks Morse & Co.	7	14	17	75,192	64
810	600	Alco (American Locomotive Co.) Supercharged	6	12½	13	40,600	2
817	327	Busch Sulzer Bros. Diesel Engine Co.	6	16½	21	88,900	36
875	300	" " " " " "	7	16½	21	101,300	35
875	257	" " " " " "	7	16½	24½	111,300	37
875	300	Cooper Bessemer Corp.	7	15½	22	90,000	55
875	300	Fairbanks, Morse & Co.	5	16	20	77,733	65
875	327	Worthington Pump & Machinery Corp.	7	16	20	84,000	103
887	277	Rathbun Jones Engineering Co.	7	16	24	95,000	93
950	240	" " " " " "	5	19½	28	—	94
954	327	Busch Sulzer Bros. Diesel Engine Co.	7	16½	21	101,300	36
1000	257	Busch Sulzer Bros. Diesel Engine Co.	8	16½	24½	125,000	37
1000	300	" " " " " "	8	16½	21	113,700	35
1000	300	Cooper Bessemer Corp.	8	15½	22	100,000	55
1000	257	Nordberg Mfg. Co.	4	17	25	104,000	82
1000	300	" " "	8	16	22	110,000	81
1000	327	Worthington Pump & Machinery Corp.	8	16	20	95,000	103
1000	327	Baldwin De La Vergne Sales Corp.	8	16	20	90,000	23

Table 2 Engine Details

Line No.	ENGINE MANUFACTURER	Model	Cycle	Number of cyls.	Bore In.	Stroke In.	RPM	Piston Speed Ft. per min.	Rated Horse-power per cyl. (Note a)	B.M.E.P. Lbs. per sq. in. (Note a)	Crankshaft Diameter, In. Main Journal	Crankshaft Diameter, In. Crank Journal	Ratio Projected area of crank bearing to area of piston
1	American Locomotive Company	—	4	6	12½	13	600	1300	90	74.5	9½	8¼	.43
2	" " " "	Superchgd	4	6	12½	13	600	1300	135	111.8	9½	8¼	.43
11	Atlas Imperial Diesel Engine Co.	—	4	4, 5, 6, 8	9	10½	514	900	34.4	79.3	5¾	5¾	.41
12	" " " " " "	—	4	6	10	13	360	780	36.7	79.0	6	6	.38
13	" " " " " "	—	4	4, 6	11½	15	327	818	50.0	77.7	7	7	.40
14	" " " " " "	—	4	4, 6	13	16	327	873	66.7	76.0	7½	7½	.37
15	" " " " " "	—	4	6	14½	18	300	900	87.5	77.7	9	9	.41
16	" " " " " "	—	4	6	15	19	300	950	100.0	78.6	9	9	.38
21	Baldwin De La Vergne Sales Corp.	VO	4	3, 4, 5, 6, 7, 8	12¾	15½	400	1033	77.5	77.5	8¾	8¾	.41
22	" " " " " "	VG	4	4, 5, 6, 7, 8	15	18½	327	1008	95.	70.3	9¼	9¼	.44
23	" " " " " "	VM	4	6, 8	16	20	327	1090	125.0	75.3	11¼	11⅛	—
31	Busch Sulzer Bros. Diesel Engine Co.	DF-17	4	3, 4, 5, 6, 7, 8	13	17	360	1020	75.	73.1	9	9	.35
32	" " " " " "	DF-17	4	3, 4, 5, 6, 7, 8	13	17	400	1133	83.3	73.1	9	9	.35
33	" " " " " "	DF-20	4	3, 4, 5, 6, 7, 8	13	20	300	1000	75.	74.5	9	9	.35
34	" " " " " "	DF-20	4	3, 4, 5, 6, 7, 8	13	20	327	1090	83.3	75.9	9	9	.35
35	" " " " " "	DB-21	4	4, 5, 6, 7, 8	16½	21	300	1050	125.	73.5	11	11	.36
36	" " " " " "	DB-21	4	4, 5, 6, 7, 8	16½	21	327	1145	136.3	73.5	11	11	.36
37	" " " " " "	DB-24	4	4, 5, 6, 7, 8	16½	24½	257	1049	125.	73.5	11	11	.36
38	Chicago Pneumatic Tool Co.	68CP	4	6	8	10½	750	1312	39.	77.6	—	—	—
39	" " " " "	88CP	4	8	8	10½	750	1312	39.	77.6	—	—	—
40	" " " " "	69CP	4	6	9	10½	720	1260	49.5	78.2	—	—	—
41	" " " " "	89CP	4	8	9	10½	720	1260	49.5	78.2	—	—	—
42	" " " " "	RHB50V	4	4	10¾	14¼	450	1069	56.3	76.6	—	—	—
43	" " " " "	RHB50F	4	5	10¾	14¼	450	1069	56.3	76.6	—	—	—
44	" " " " "	RHB50S	4	6	10¾	14¼	450	1069	56.3	76.6	—	—	—
45	" " " " "	RHB50A	4	8	10¾	14¼	450	1069	56.3	76.6	—	—	—
46	Clark Bros. Co.	FD	4	3, 4, 6, 8	10	12	600	1200	50.0	70.0	7	6½	.48
47	" " "	FD	4	3, 4, 6, 8	10	12	720	1440	66.9	78.0	7	6½	.48
48	" " "	RAD	2	3, 4, 5, 6	13	14	330	770	87.5	56.5	8	8	.33
49	" " "	RAD	2	8	13	14	330	770	87.5	56.5	11	8¾	.36
51	Cooper-Bessemer Corp.	EN	4	3, 4, 6, 8	8	10½	600	1050	31.9	79.8	6	5⅝	.53
52	" " " "	FP	4	3, 4, 6, 8	9	12	514	1028	38.7	78.1	6⅜	6⅛	.40
53	" " " "	GN	4	3, 4, 6, 8	10½	13½	450	1013	53.2	80.0	7½	7½	.49
54	" " " "	JS	4	5, 6, 7, 8	13	16	400	1067	84.4	78.6	9	9	.42
55	" " " "	LS	4	5, 6, 7, 8	15½	22	300	1100	125.0	79.3	11	11	.47
61	Fairbanks Morse & Co.	32E14	2	3	14	17	300	850	75.0	37.8	8	8	.37
62	" " " "	32E14	2	4, 5, 6	14	17	300	850	75.0	37.8	9	9	.42
63	" " " "	33F12	2	5, 6, 7	12	15	400	1000	100.0	58.3	8	8	.42
64	" " " "	33E14	2	5, 6, 7	14	17	300	850	115.0	58.0	9	9	.44
65	" " " "	3E316	2	4, 5, 6, 7, 8, 10	16	20	300	1000	175.0	57.4	10	10	.43
71	Ingersoll-Rand Co.	S	4	3, 4, 5, 6, 7, 8	10½	12	720	1440	75.0	79.3	—	—	—
81	Nordberg Mfg. Co.	—	4	6, 8	16	22	300	1100	125.0	74.5	11½	10½	.40
82	" " "	—	2	3, 4	17	25	257	1072	250.0	67.8	13	12	.37
91	Rathbun-Jones Engineering Co.	—	4	3, 4, 5, 6, 7, 8	11	18	360	1080	58.1	74.7	6⅞	7⅛	.39
92	" " " "	—	4	3, 4, 5, 6, 7, 8	13¼	22	300	1100	86.7	75.4	8½	8¾	.39
93	" " " "	—	4	3, 4, 5, 6, 7, 8	16	24	277	1108	126.7	75.0	10	10.4	.39
94	" " " "	—	4	5, 6, 7, 8	19½	28	240	1120	190.0	75.0	12½	13	.39
95	Waukesha Motor Co.	NKHU	4	6	7	8½	950	1346	33.3	85.	3¾	3¼	.536
96	" " "	LRHU	4	6	8½	8½	900	1275	46.6	85.	4¼	4	.414
101	Worthington Pump & Mchny Corp.	CC	4	3, 4, 5, 6, 7, 8	10¾	14½	450	1088	56.3	75.2	7½	7½	.45
102	" " " "	DD	4	3, 4, 5, 6, 7, 8	13¼	17½	360	1050	83.1	75.7	8½	8½	.48
103	" " " "	EE	4	3, 4, 5, 6, 7, 8	16	20	327	1090	125.0	75.2	11	11	.44

Note (a) Figures given are for the largest engine of the model.

SUPERCHARGED ENGINES FOR PIPE LINES

By J. B. Harshman
General Superintendent
Stanolind Pipe Line Company

Results of Five Year Experience Show That Fifty Percent Increase in Horsepower of Existing Power Equipment Is Economically Feasible.

THE ambition of engineers and designers of Diesel engines for many years has been to build an engine that would produce more horsepower from a given cylinder size. The limiting factor ("Brake Mean Effective Pressure") could not be raised above a certain point without encountering excessive operating temperatures, resulting in inefficient operation and high maintenance costs. Since most four-cycle engineers were designed against inertia forces and not combustion forces, anything which increases the engine capacity by utilizing these oversized parts is an economic accomplishment; therefore, it was only natural that consideration would be given to mechanical means of charging the cylinders with air at pressures above atmospheric.

The Buchi system consists of a centrifugal air blower which is mounted on the same shaft with a single impulse turbine driven by the exhaust gas of the engine. The turbine and blower are mounted in the same case or housing with a system of labyrinth seals to prevent leakage from one compartment to another. The mean pressure on the exhaust gases ahead of the turbine is generally from two to three pounds above atmosphere. The charging air from the blower is from three to four pounds above atmospheric pressure. Extra wide exhaust and intake cams are provided so that both exhaust and intake valves are open simultaneously, giving an overlap of 120 crank angle degrees.

While both valves are open, the charging air passes over the top of the piston, then through the exhaust valve. Thus the cylinder is scavenged of burnt gases. The large volume of comparatively cool air in passing through cools to some extent the piston head, valves and upper cylinder walls, and reduces the exhaust temperature. As the piston moves from upper dead center downward on the intake stroke the cylinder is thoroughly charged with fresh cool air at pressure exceeding atmospheric.

Engines with four cylinders and over have a system of multiple manifolding of the exhaust to permit complete scavenging of one cylinder before the exhaust valve opens on another cylinder. Thus, overlap in the exhaust manifold is avoided. At the same time, efficient fluctuations or pressure waves are made use of in the exhaust manifold to assist in scavenging the cylinders.

This division of exhaust manifolds is carried from the cylinder to inlet of the turbine. Figures No. 1 and 2 show typical arrangements for manifolding four and five cylinder engines.

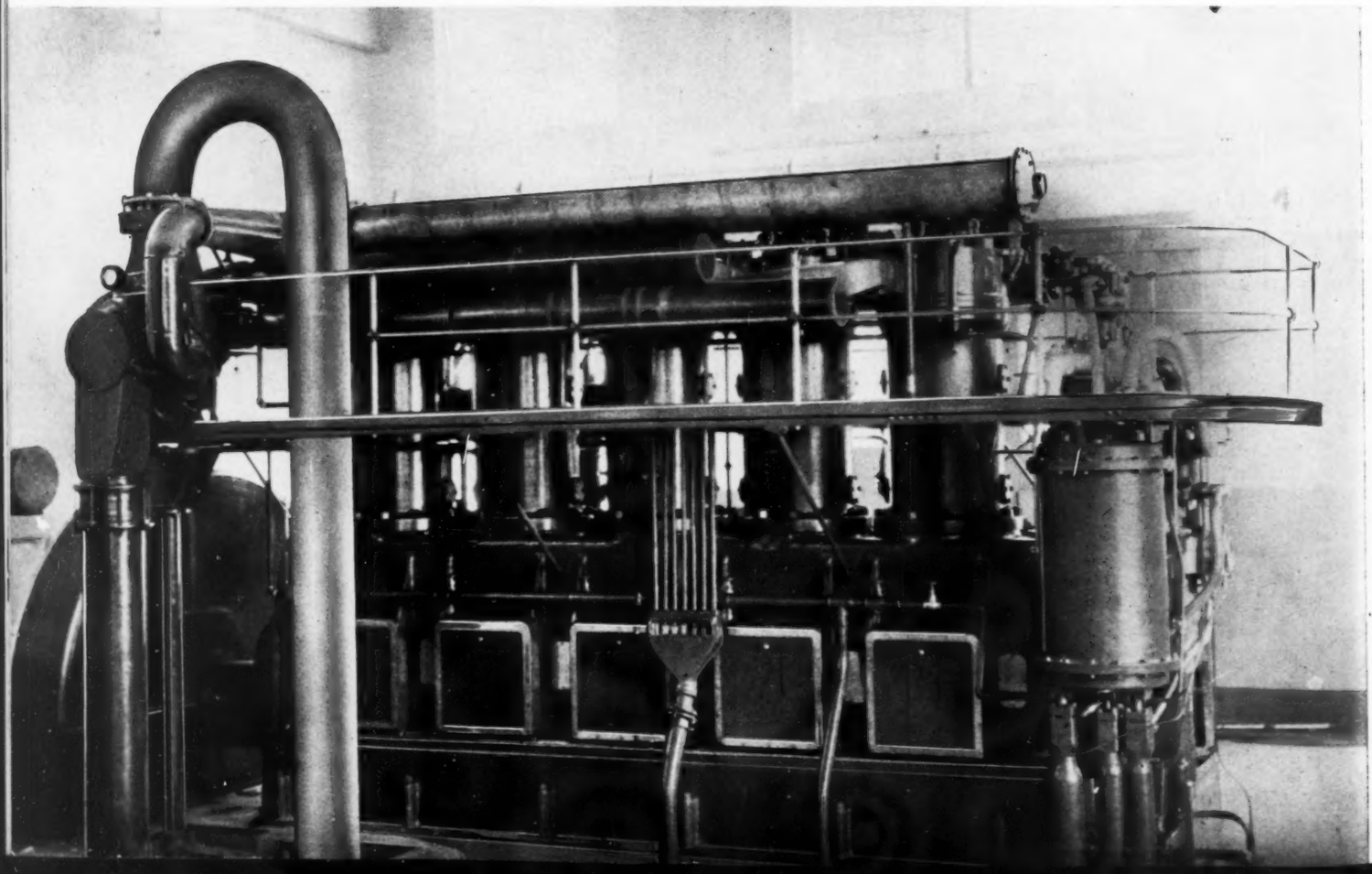
Other than the division of the exhaust manifolds and the installation of larger inlet and exhaust cams, very few changes in the engine are required. The fuel system is adjusted to give a longer period of injection, the increase in the amount of fuel being proportional to the extra horsepower to be developed. The compression space must also be increased due to the higher pressure of the air at the beginning of the compression stroke.

The Buchi turbocharger can be set into the piping at either end of the engine at the height of the exhaust manifold, or it may be set on the floor and the piping extended from the engine to interconnect with the turbocharger.

Some of the first experiments in supercharging were made in Europe nearly thirty years ago;

Condensed from a paper presented before the Oil and Gas Power Division of The American Society of Mechanical Engineers at Kansas City, June 11, 1941.

American made turbocharger installation on a 500 h. p., five-cylinder, four-cycle, Diesel, air-injection pipeline engine which increased the rating to 750 h. p.



however, it was not until 1928 or 1929 that American engineers began to realize the possibilities of satisfactorily increasing horsepower by this method. The first commercial installation in the United States, of which the author has record, was made in 1928 by an American manufacturer in a western state. The elevation of the plant was 9,000 ft. above sea level and the engine was supercharged with a belt driven rotary blower to produce its normal sea level rating.

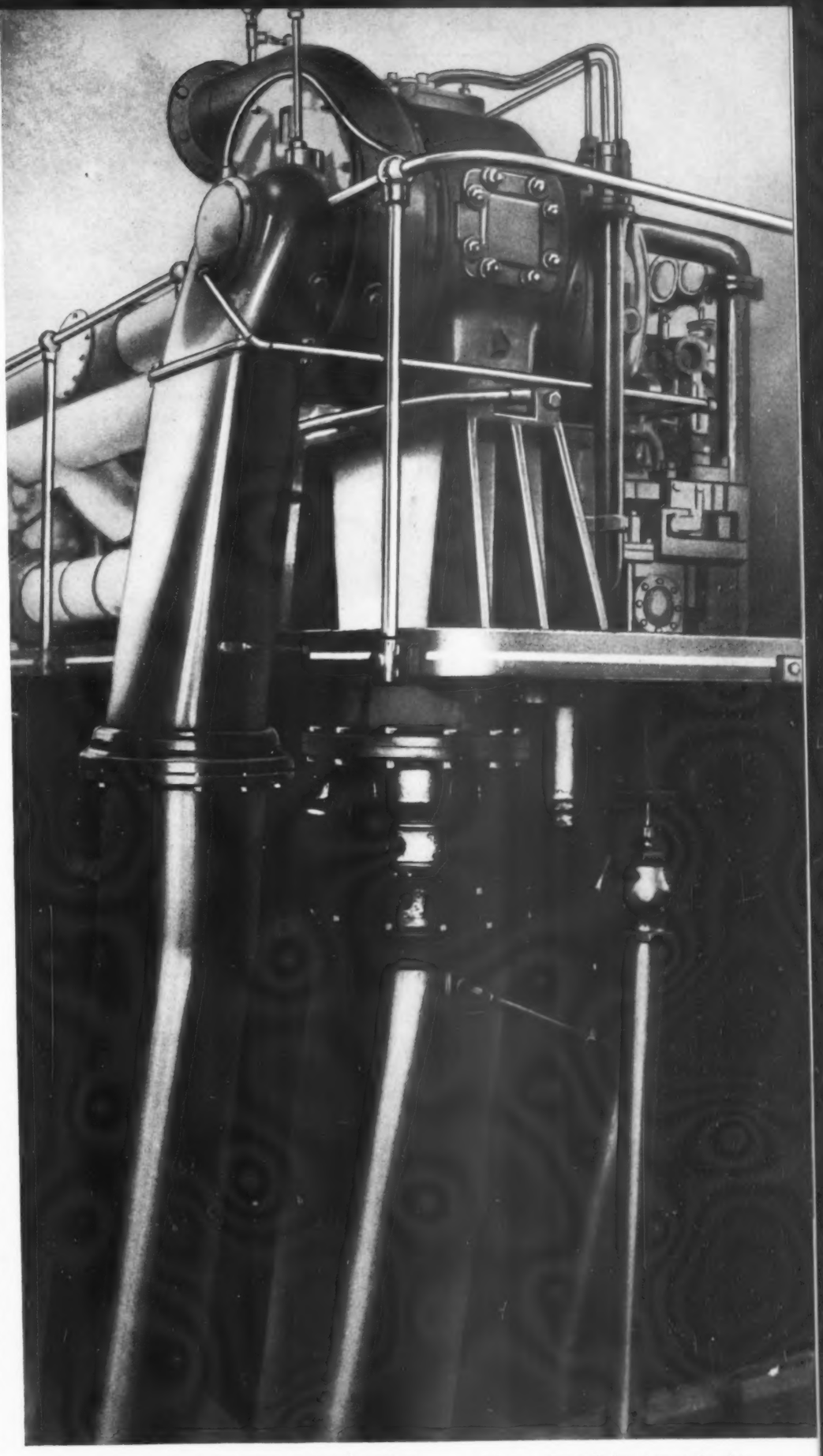
About 1935, American Diesel engine builders became interested in the accomplishments of certain European engine builders in the use of exhaust turbochargers. Early in 1936, several of these exhaust turbocharger units were imported to this country by engine builders primarily for study and experimental purposes.

Since that time numerous installations of supercharged engines have been placed in service making use of the Buchi system. The greatest percentage of these are in locomotive service where maximum horsepower with minimum weight and space requirement are factors. There are, however, several stationary installations in use, two or which are in service on a major pipeline.

In the early part of 1936, Stanolind Pipe Line Company was faced with the problem of increasing the pumping capacity at one of its trunk line stations. The capacity desired was not sufficient to justify installation of an additional large unit, therefore, consideration was given to the possibility of supercharging one of the existing engines in the plant and increasing the speed of the pump by installation of new gears of a lower ratio. Since the Buchi system seemed to have greater possibilities than other methods considered, an order was placed with the engine manufacturer for the turbine. The manufacturer also took the responsibility for doing the necessary engineering work and supplying the new cams, exhaust manifolding, etc., for the complete installation.

In October, 1936, Stanolind Pipe Line Company placed in service its first supercharged engine. The engine was a four-cylinder, four-cycle type 16.5 in. bore by 24 in. stroke, rated at 400 h. p. at 200 r. p. m. The turbocharger was purchased for an increase of twenty-five per cent in engine output. The increased horsepower was accomplished without difficulty as far as engine troubles were concerned. However, trouble was experienced from the start with the ball bearings in the turbocharger. This turbocharger was built to operate at a top speed of 20,000 r. p. m. and operated at 15,000 to 16,000 r. p. m. when carrying 500 engine horsepower. Apparently the design of the ball bearings was inadequate for the thrust load to which they were subjected and it was found that their life varied from a few hours to a maximum of 2,000 hours.

After about a year and a half of operation of this unit under a serious handicap due to bearing troubles in the turbocharger, during which time



European made, turbocharger installation on a 500 h. p. five-cylinder, four-cycle pipeline Diesel engine increasing the horsepower rating to 750 h. p.

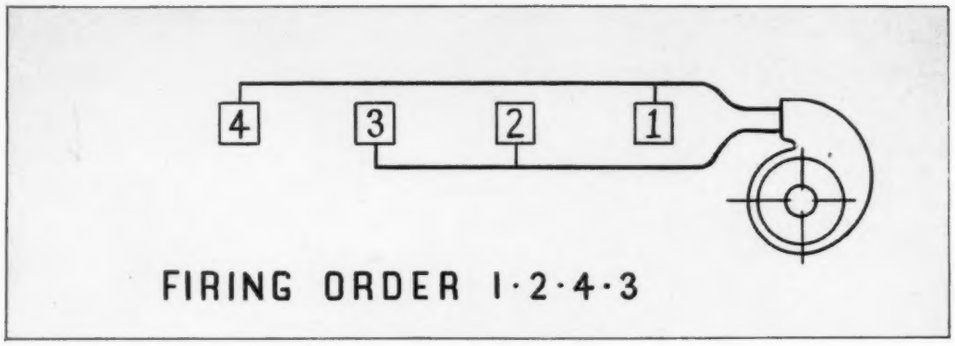


Figure 1

the turbocharger was once returned to Switzerland for repairs, it was decided to ship the machine to an American engine builder and have the ball bearings replaced with sleeve type bearings. During the period of tests on the supercharged pipe line engine this engine builder had placed several supercharged Diesel locomotives in service and had encountered similar trouble with the ball bearings. Sleeve type bearings were developed for the turbocharger on the locomotive engines which had proved very successful. The ball bearings were replaced in the turbocharger owned by Stanolind with bronze sleeve type bearings, after which the machine was again placed in service. Lubrication difficulties were then experienced with the new sleeve bearings and one bearing failed after nineteen hours operation. The bearing was replaced, the lubrication problem corrected, and another test was started.

A twenty-five percent increase in engine horsepower was satisfactorily obtained; however, by this time other American engine builders were becoming interested in the possibilities of supercharging and some tests had been made in which seventy-five and one-hundred percent overload had been reached. Due to the expense involved in such an installation, it was decided that supercharging could not be economically justified for a twenty-five percent increase in engine horsepower. After consulting the engine builder, a decision was made to conduct tests using the same turbocharger for a horsepower increase of fifty percent. Certain changes were made in the nozzle rings of the turbocharger to prevent exceeding the 20,000 r. p. m. speed limit. This test was a failure due to insufficient capacity of the turbocharger, and the turbocharger was subsequently badly damaged due to overloaded and overheated conditions.

Although many discouraging problems were encountered in the test of this first supercharged engine, sufficient information was obtained to convince all concerned of the practicability of supercharging, particularly by the Buchi method.

In August 1940, the second supercharged engine was placed in service by Stanolind. This engine was of the four-cycle type with five 16¼ in. by 23½ in. cylinders, having a normal horsepower rating of 500 at 225 r. p. m. In October 1940, another turbocharger was placed in service on a 500 horsepower, five cylinder, 16½ in. by 24 in. engine. The Buchi System was used on both of these installations; however, the turbochargers were much larger machines with a full load speed of only 12,000 r. p. m. Both turbochargers were equipped with babbitt lined sleeve type bearings. This equipment was purchased with the idea of increasing the engine output fifty percent or from 500 to 750 horsepower. The gear ratio was changed on the pumps, increasing the pump speed from 47 to 55 r. p. m., in order to make full use of the increased horsepower. These units have been in continuous operation since that time. The only difficulty experienced is that the load balance cannot be maintained on the various cylinders of the engine due to overlap of the exhaust impulses in the three-cylinder manifold, as shown in Figure No. 2.

Negotiations are now being carried on with the intention of developing a turborcharger with three openings in the exhaust inlet casing for five-cylinder engines.

In the firing sequence shown in Figure No. 1 no two cylinders exhausting into the same manifold follow each other. In Figure No. 2, showing the manifolding of a five-cylinder engine, it will be noted that numbers one and three cylinders follow each other in firing order in the same manifold, which condition is unavoidable in a five-cylinder engine unless three, or more, manifolds are used. Exhaust manifolds should be designed to prevent this condition, otherwise one of the cylinders affected by the overlap of the exhaust will not scavenge properly and will be overloaded.

Sufficient experience has been gained from the installations described above to prove that increasing the horsepower of existing pipe line pumping installations is not only practicable, but economically justifiable. For instance, two hundred and fifty horsepower increase can be obtained by supercharging a five hundred horsepower engine for an investment of approximately twelve thousand five hundred dollars, including the cost of new gears for increasing the speed of the pump. This is equivalent to fifty dollars per installed horsepower which is less than half the cost per installed horsepower when purchasing additional pumping units.

The use of supercharging has other advantages which make it attractive for pipe line service. For instance, it frequently becomes necessary to provide a temporary increase in horsepower and pumping capacity at trunk line stations handling oil from flush fields or for a temporary peak load to certain refineries. After this peak load requirement no longer exists a large investment is usually left idle or operating at low capacity. If this peak condition is met by supercharging, the turbocharger and other equipment used in its operation may be moved at a nominal cost to another station, where the additional capacity can be used to advantage.

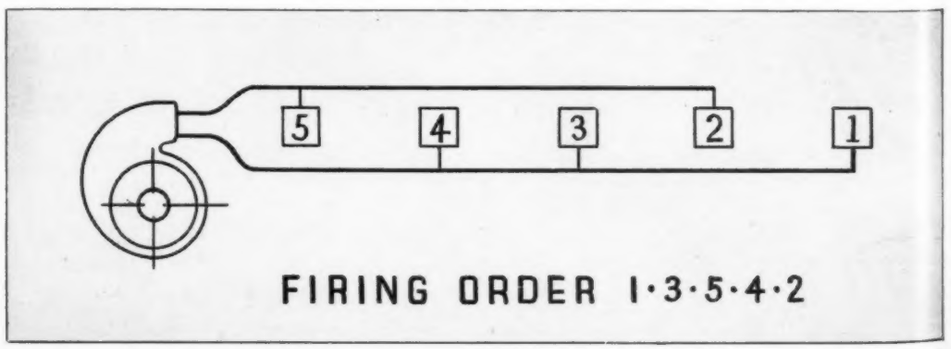
About the only disadvantage actually encountered in the operation of the last two installations has been inability to operate these units at loads below the original rated horsepower of the engine. Although the exhaust driven turbine is supposed to compensate automatically for load variation, it appears that an excess amount of air is forced into the engine for the quantity of fuel consumed, which results in poor combustion. After operating at reduced loads for a few days it is necessary to remove the turbine rotor and clean out the carbon accumulations.

Experience in the operation of the three turbochargers on pipe line pumping units indicates that the following improvements should be made for maximum success.

1. The proper method of manifolding to prevent overlapping of exhaust from different cylinders.
2. Provision for some method of regulation of air at low loads to insure proper combustion.
3. Design of turbocharger should be such that it can be installed in different positions to simplify piping and to permit adaption to existing piping. The general appearance of present installations indicate that little or no thought has been given to obtaining a uniform and workmanlike piping job.

Regardless of the difficulties experienced with the first installation and the undesirable features mentioned above, it is believed that supercharging of Diesel engines for increasing the capacity of existing installation in pipe line service has tremendous possibilities and that its use will become general throughout the industry.

Figure 2



Trailing The Source Of Oil

WHERE and how does petroleum originate, and how does it move from one place to another under the ground? From the standpoint of wildcatting addicts who would much rather know where the oil is than how it got there, this question will seem more or less irrelevant and academic. But in the broad view, every ascertainable fact that can be learned about petroleum will sooner or later come to have some practical bearing on how and where to find oil.

For instance, this business of finding oil is getting more and more difficult. As the known pools of oil are depleted and the discovery rate of new fields is reduced, petroleum geology must offer more efficient methods of locating additional accumulations if the development of reserves is to keep pace with consumption.

As an example of the necessity for a more thorough insight into the source and genesis of petroleum, consider the following unhappy situation. A geophysical crew succeeds in locating a structure. This structure is first indicated, let us say, by a gravity survey. Then a seismograph outfit outlines the structure, finds that it has excellent closure and has large dimensions. On this excellent showing an expensive wildcat well is sunk to a depth of five thousand feet, more or less, without finding a drop of oil.

What was lacking here? The structure was recognized as ideal, and it was defined with precision; it was, apparently as well adapted to contain oil as dozens of other structures that have had less geophysical evidence to recommend them.

This raises the very pertinent question as to why one structure should contain oil in abundance while another structure is dry. The practical side of this question is how to find out in advance, if possible, whether or not the structure is likely to be dry. The fact is that after a structure has been formed by geologic processes it will be of no interest to drillers if it is not filled with oil from some source. If there are no source beds in the vicinity the chances are that the wildcatter will have another dry hole.

For these and allied reasons the Research Committee of the American Association of Petroleum Geologists has sponsored a broad inquiry into the formation and underground movement of petroleum. The results of this inquiry have been published as a closely printed monograph of 180 pages in the Colorado School of Mines Quarterly (Vol. 36, 1941, No. 2. $2.00) entitled "The Time of Origin and Accumulation of Petroleum." The editors of this monograph, F. M. van Tuyl and Ben H. Parker of the Colorado School of Mines at Golden, Colo., started their extensive investigation as follows:

They sent a questionnaire to petroleum geologists all over the world asking for statements of fact within their knowledge that would show a relation between source beds and oil and gas fields, and how the oil from these beds might have passed into the structural traps. The editors have made a commendable effort to sort out and correlate the large mass of fact and opinion that reached them. The questions raised about as many new problems as they solved.

One of the questions was designed to learn what new evidence could be reported bearing on the present-day generation of hydrocarbons. This is a very interesting and not wholly irrelevant question even though it seems to be of no immediate help to adventurous wildcatters. Wide publicity has been given to statements that petroleum is now being formed in nature at a faster rate than it is now being produced. If that is so, it might not be necessary to worry about the future of the oil business.

The consensus of the experts is that petroleum, as such, is not being formed anywhere under present-day surface conditions, but it is very evident that nature is now preparing, on a large scale, the raw material out of which petroleum may be formed by further natural processes. In many places throughout the world animal and vegetable materials are being prepared for geologic burial. Much of this material contains non-saponifiable waxy and oily substances which by slow bacterial processes, intermolecular reactions or physical processes are capable of ultimate transformation into petroleum hydrocarbons. Every existing coral reef is a gigantic storehouse of such source material. Diatoms and other plankton which flourish in countless numbers in all salt or fresh waters contain protopetroleum or its parent substances. These organisms are ceaselessly dying and accumulating in favorable places where they may be buried by muds, clays or other products of erosion. Whether this present day burial of the parent material of petroleum is actually proceeding at a rate equal to or exceeding present day extraction of petroleum cannot be definitely affirmed, but it is hardly to be doubted that it is occurring on a large scale.

When the protopetroleum has been buried it next becomes a question as to when and under what conditions the transformation into petroleum will occur. There is a good deal to show that, in general, a considerable time is required. It seems to be significant that no important deposits of oil have been found in late tertiary or quaternary formations that could surely be regarded as having originated in these formations, although these geologically young formations often contain ether-soluble material which is on the way of becoming petroleum. On a broad view, it seems that indigenous real petroleum or its sources are hardly to be looked for in formations older than pliocene. If that generalization holds true, then the raw materials of protopetroleum now accumulating will be of no interest to wildcatters for one or more eons of geologic time. This mostly excludes young geological formations from consideration as source beds from which structures might be filled.

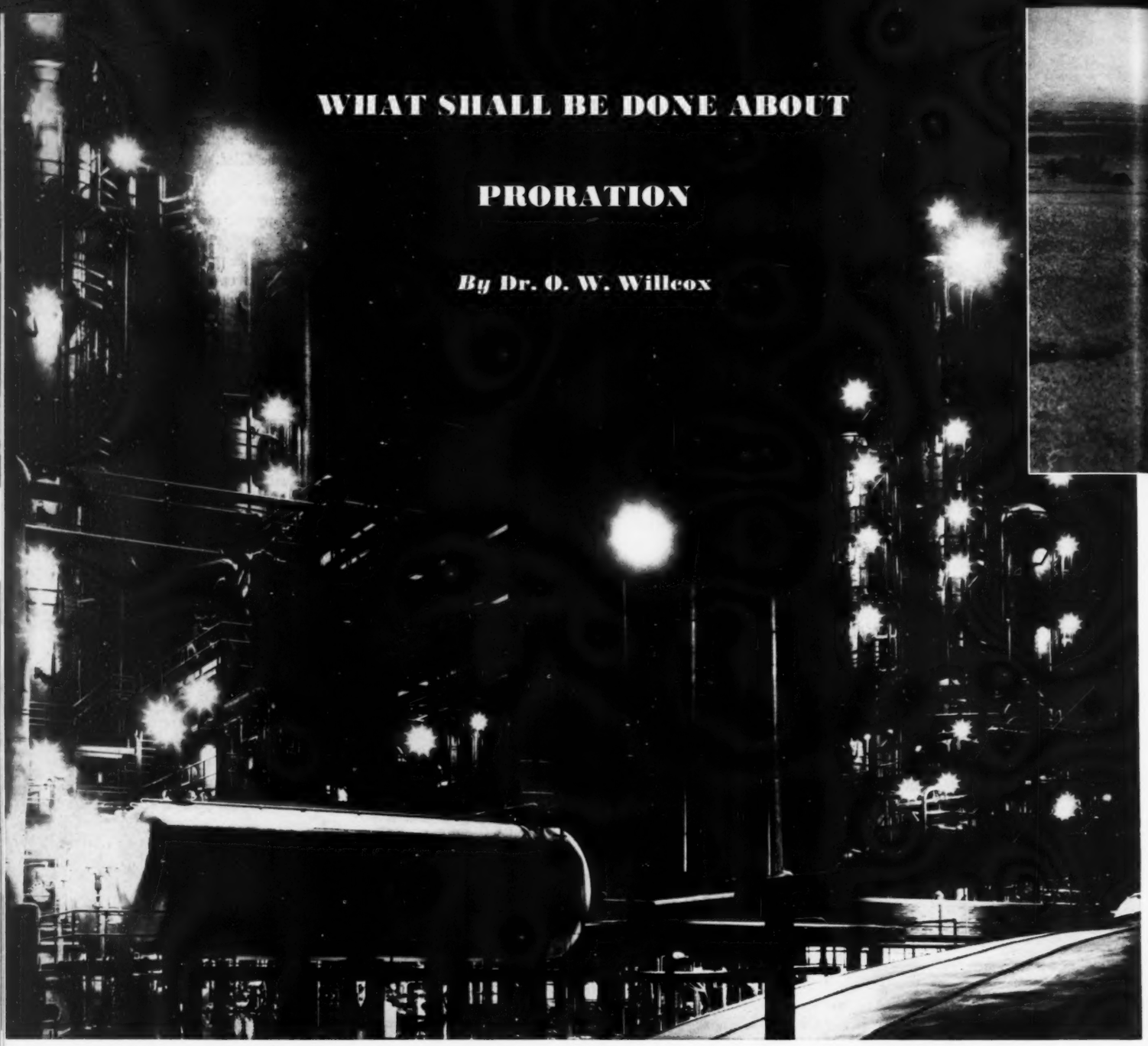
As further evidence that a long time is required for transforming organic material into petroleum is the fact that although under special local conditions petroleum may be formed and accumulated at depths of less than two thousand feet, it appears that much deeper burial is more favorable, largely for the reason that there must be an accumulation of several thousand feet of sediment in which geologic folding and faulting may provide traps for holding the oil.

Among other ways, it is here that the petroleum geologist comes into collaboration with the geophysicist. The geologist not only has to review the evidence obtained by the geophysicist as to the presence of a structural trap, but he has to consider the probability that this trap has been filled. Are there any source beds that are old enough and deeply buried long enough for the organic matter they contain to have been transformed into petroleum? These possible source beds may be old muds where organic matter was putrefied in some quiet basin and have now become oil shales, although limestones, clays and even sands may have been the original burying ground. Often a bed of limestone or a sand gives evidence that the oil was generated in the bed itself and stayed there until tapped by the drill. In such cases the character of the oil will be a reflection of the character of the original matter.

After petroleum has been generated in a buried formation it may or may not stay there. If the overburden is very heavy the oil in shaly material will most likely be squeezed out, much as water may be forced by pressure out of a wet sponge. It is therefore of importance to discover the channels through which the oil might escape and wander about until it finds itself in a structure that will hold it until the geophysicist and the wildcatter arrive on the scene. Or the avenue of escape might be provided by faulting or equivalent geological disturbances since deposition.

Putting all these things together the petroleum geologist balances the possibilities that a structure may turn out to be oil-bearing or dry. If there is any evidence of source beds in the vicinity, together with evidence of sand beds, faults or other channels through which oil might migrate, the proposition to drill into the structure may not appear as risky as usual.

This does not mean that risk is eliminated when all these favorable factors are found in association; it may mean only that the percentage of risk has been slightly lowered. Nevertheless, those who risk their money in wildcatting cannot afford to overlook any possible lead, however faint. For this reason the publication of this monograph, which throws sidelights on circumstances too numerous to be mentioned here, is a real public service to petroleum geology.



WHAT SHALL BE DONE ABOUT PRORATION

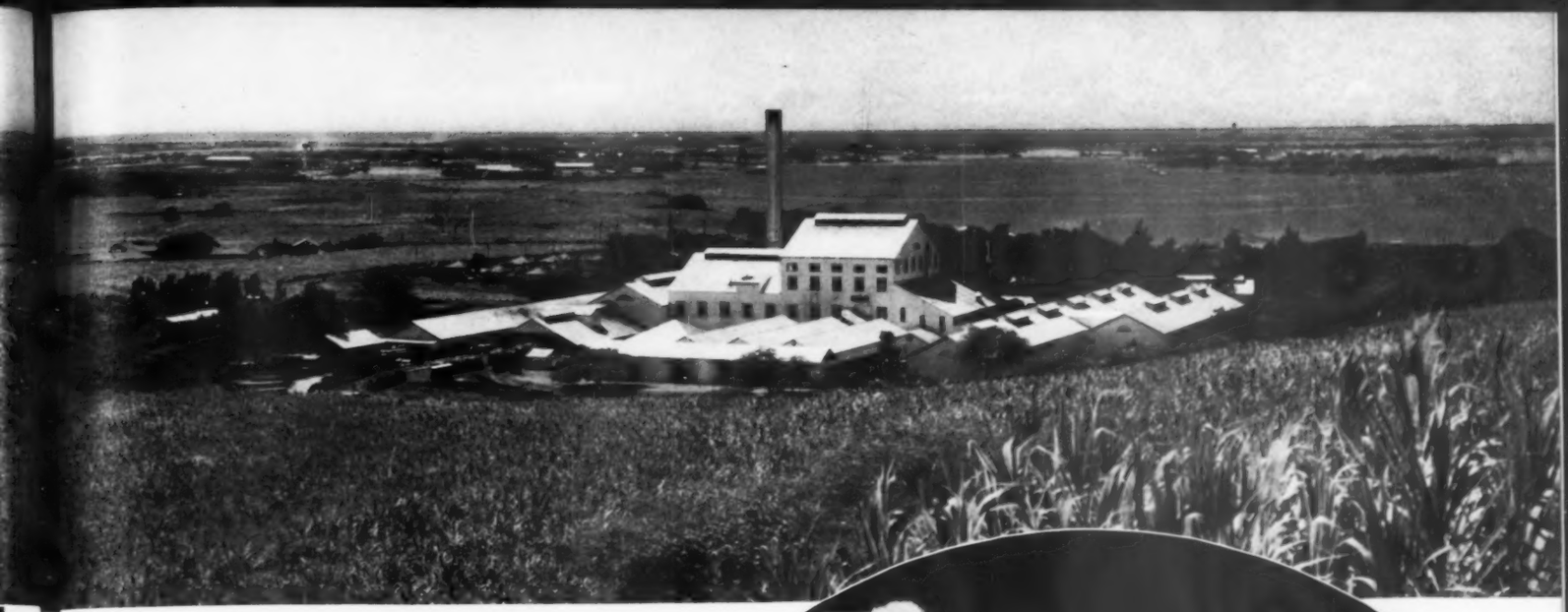
By **Dr. O. W. Willcox**

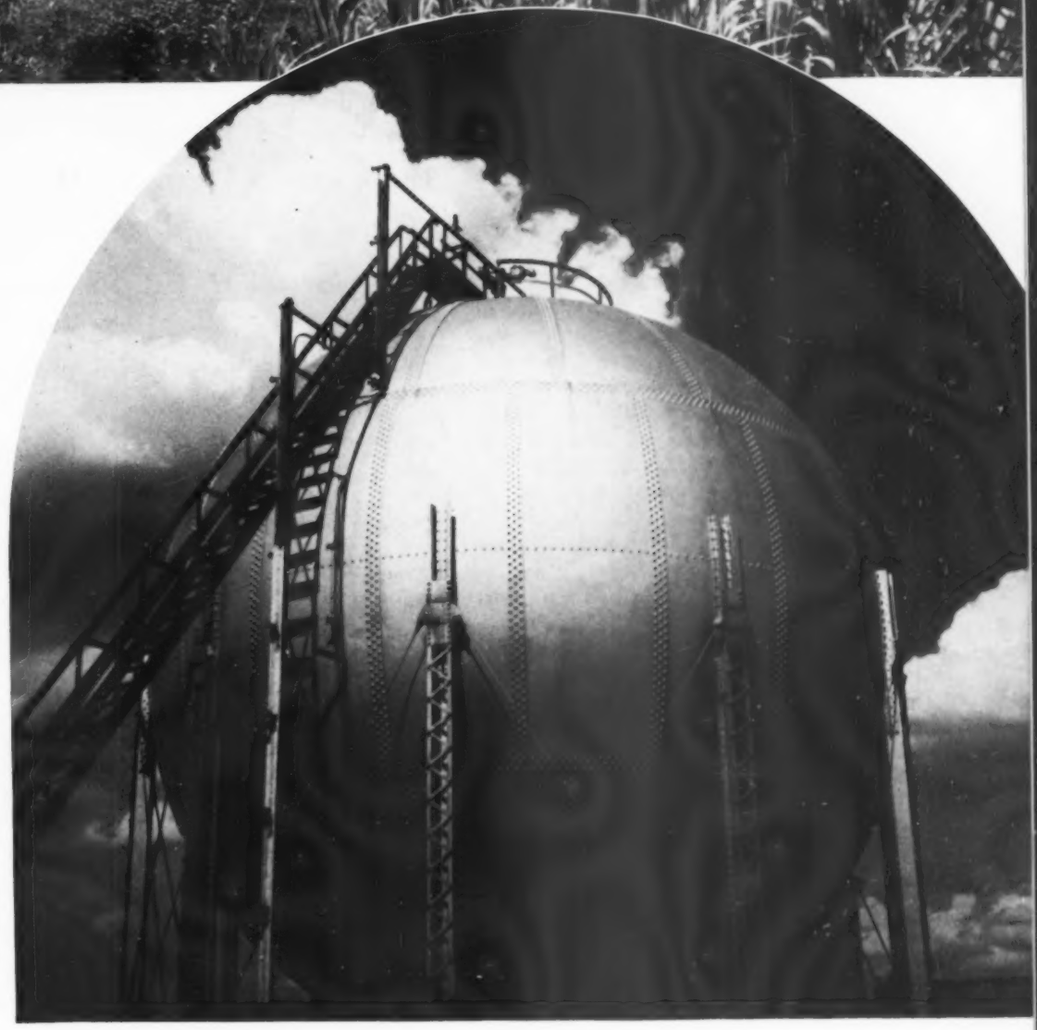
Second of a Series, the First of Which Was Published in May, Suggesting the Possibility of Applying to the Oil Industry a System of Proration Heretofore Successfully Used in the International Sugar Industry

THE PURPOSE of this series of articles, as announced in the first installment, is to acquaint the petroleum industry of the United States with developments which show the ultimate form that may be given to a system of industrial proration, with limitation and control of production in the interest of both the industry and the general public welfare.

It was stated that in comparison with what is to be found elsewhere the system of proration now partly in effect in the petroleum industry is to be regarded as incomplete and, relatively, in a state of arrested development. The writer has thought that if the oilmen of the country were fully informed about how proration has been worked in the world-wide sugar industry they might gain a few ideas that would be useful in straightening out their own tangled affairs and in establishing closer and more harmonious relations with the government and the public.

In the preceding article the outline of proration in the sugar industry was sketched up to the point where the industry and the public (represented by the respective governments) had settled their relations, in principle. The ruling principles of this settlement were that the now saturated industry was to be maintained intact, or as a whole; that the business of the industry was to belong to the whole industry and to be divided *prorata* among the members according to their previous production records; and that the total production of the industry should be limited to an amount which would exactly balance consumption. As no member of the industry should have his share of the business taken away or impaired by another member, so also would outsiders or newcomers be prevented from coming in to dilute or whittle down the shares of the charter members because the industry had reached a state of oversaturation in which further overcrowding would be contrary to the public interest. The public accepted the principle that consumers should be required to pay a





Lessons learned in the proration of sugar in many parts of the world might be applied to the oil industry in a modified form with beneficial results.

price that was no more than reasonable and no higher but no less than is required to cover the full technological and social-economic costs of the industry *as a whole.*

In effect, the industry as a whole was to receive a total income that would cover its costs and profits as a whole, and was to present, for ratification by the government and the legislature a form of agreement that would equitably divide the business among all the members on a pro-rata basis. Or, if there was any deviation from strict arithmetrical proportion, it should be to favor the weaker and the technologically least efficient producers whose continued functioning had to be assured, without unduly increasing the price that the public would be called on to pay.

The sugar industries of the world, each in its own country, had to consider whether, and how, they would accept the benefits and conform to the obligations contained in this proposition. There was, in all cases, a practically unanimous opinion that a condition of oversaturation and unrestrained competition, in which production constantly exceeded consumption, was responsible for low prices that put in jeopardy the economic existence of even the strongest concerns. Against this decidedly unwelcome condition the industry now had the prospect of stability and security. There was to be no more cut-throat competition and no market fluctuations. Every man was to have and to keep his share of the business and he was to have a price that would allow him to stay in the business. Here was, at last, real economic security for all established members of the industry. All that was now needed was for the men in the industry collectively to agree to conform to the principles of live and let live among themselves and with the public under government approval.

The astonishing fact of this matter is that the members of great national sugar industries, when confronted with the proposition in this form have accepted, practically *en masse* the principle of the golden rule of doing unto others as you would wish to be done by. As a historian of the social-economics of the world-wide sugar industry, this writer has taken note of, and recorded, numerous nation-wide agreements that have been framed on this principle, and ratified by the written ballots of seven-eighths to nineteen-twentieths of all the elements concerned.

The reasons for this practical unanimity in great bodies of sugar agriculturalists and industrialists the world over, regardless of racial, political and geographic differences, are not hard to define. Human nature is practically the same everywhere, and with comparatively rare exceptions all men are fair-dealing, socially-minded and ready at all times to sink a measure of personal advantage in collaboration for the common good, provided that their personal welfares are not too seriously impaired. Few men will

respect the economic security of others unless their own security is assured. But give them this assurance and at least nine out of ten normal men will be glad to let other men have a living, and will give up something to help the less fortunate. It is, or so it seems, because of this universal trait of normal human nature that sugarmen, presented with the chance of business stability and a price that would sustain the industry as a whole, were willing and able to contrive an arrangement that would give the consumers sugar at a price reasonable enough to receive governmental and legislative approval, and still keep a place for even the smallest and most inefficient established producers whom the governments insisted should not be sacrificed.

Here is something new in practical social-economics. In a fully developed system of industrial proration there is no such thing as a marginal producer who is in danger of becoming submarginal when prices swing downward, because his colleagues and his government (with the public approving) join hands to keep him afloat by means of special concessions.

The first and most important task confronting an industry that meets in plenary conference to devise a nation-wide, all-inclusive system of proration is to divide the business on a basis that will not be arbitrary or discriminatory. The method adopted in most prorated sugar industries is the so-called peak-year scheme, according to which the highest annual tonnage production attained by a factory during its past history is taken as its rated capacity, and its relative share in the total production is computed on that basis. However, a strict application of this arithmetrical proportion was generally found to be inconsistent with the two main objects that had to be achieved; a low fixed price to the consumer and preservation of the weaker members. As a way out it was generally decided to give to the weaker brethren certain preferences and concessions. It is extremely interesting and important to note the nature and extent of such concessions. Some relate to details peculiar to the sugar industry, but others are capable of broad application to any industry, including the petroleum industry, and are suggestive of a new order of social economics that is vastly different.

(1) Minimum Production Quotas. In all the agreements it is provided that enterprises which are producing less than a certain minimum quantity shall suffer no restriction, and if possible will be given a quota at least equal to that minimum. (In sugar this applies especially to small farmers, in petroleum it would apply to the great mass of stripper wells.

(2) Minimum Manufacturing (Refining) Quota. Every manufacturing or processing plant is to be given a production quota that will be large enough to enable it to produce profitably at the fixed price which the government and the public will regard as reasonable. For instance, if a 2000-ton (or bbl.) enterprise cannot operate profitably at the fixed price but might do so if its equipment were modernized and its quota increased to 4000 tons (bbl.) its quota will be raised to that figure by giving something from the quotas of the larger enterprises which can operate on slightly lower quotas.

(3) Revolving Fund for Modernization. To enable small enterprises to modernize they can have loans to buy suitable equipment. This fund is raised by an assessment levied on the tonnage production of the whole industry. Naturally, the bigger enterprises will pay most of this assessment, which is collected in a manner to be described later.

(4) Relief from Export Obligations. It is a peculiarity of the sugar industry that there is a large surplus which cannot be absorbed by the domestic market and which must be exported at a very low price. In a prorated industry all enterprises must bear their shares of this burden, but it is agreed that the export requirement shall be waived where it would cause hardship, which again is mostly assumed by the stronger enterprises to relieve smaller units.

(5) No Manufacturing Enterprise (Refinery) to be Deprived of Raw Material. The agreement provides that every processing enterprise not possessing its own source of raw material shall at all times be enabled to procure enough to attain its prorated output of finished goods. This would apply to small refineries.

(6) Relief from Transportation Hardships. Producing enterprises (in sugar, farms; in petroleum, oil wells) remote from processing centers, and processing enterprises (refineries) remote from consuming centers, are to be put on a plane of complete economic equality in freight costs with enterprises that are most conveniently located with respect to markets and raw materials. (The writer will here advise the reader to take especial note of this feature of a proration agreement; it is one of three principal keystones of a remarkable new order in social-economics and will be more fully discussed in the third installment of this series.)

(7) Relief from Special Hardships. In this process of drawing up a proration agreement that would be acceptable to the public and to a great majority of the industry there were generally always some enterprises which, on account of special difficulties affecting them, could not be kept alive on the agreed fixed price, even with the concessions above listed. These cases were taken care of by an arrangement whereunder the especially handicapped enterprises are given a higher price for their product than is given to the others. In other words, in the division of the total income of the whole industry arising from the one fixed price paid by the public, the ablest enterprises take a smaller proportional share in order that these hard cases may have an income permitting them to operate.

In reviewing the above features of a modern, complete and nation-wide system of industrial proration, a reader will get the impression that the process of making a proration agreement consists largely of a succession of concessions and renunciations made by the strong to the weak. The big fellows, in effect, reach down into their pockets to help the little fellows improve their positions. These marginal and even submarginal enterprises, which in our present age-old system of unlimited competition and survival of the fittest, should expect to be sunk in order that the ultimate consumer may buy in the cheapest of all possible markets, are to be kept afloat by a fixed price that is high enough to leave the big fellows something even after they have carried their generosity and neighborliness to such unusual lengths. For, to be sure, the big fellows would be careful not to give away too much, but would insist on keeping enough to assure themselves of a reasonable profit; nothing would be farther from their thoughts than economic suicide.

But it is important to note that in all cases the big fellows have seen it to their advantage to give away a good deal. The prospect of a stable market and a stable price, and hence a stable income on a volume of business somewhat smaller than a theoretical arithmetrical quota has proved to be a powerful incentive to moderation in the demands of the possessors of large blocks of industrial capital. We have only to look at the general investment market to see that a universal trait of human nature is here at work. Which bonds pay the highest

interest, and which stocks sell at the largest discount? They are the securities of enterprises which are effected by the greatest risks, and which depend largely on the hope of speculative profits. Remove the risk and the speculative element, and investors gladly content themselves with moderate returns. It is exactly on that principle that the big and strong elements of a prorated sugar industry have contented themselves with a moderate but sure and steady return, and this is one of the reasons why it has been possible to establish a fixed price that the government would approve and the public not resent, and yet avoid destruction of the marginal producers. (Another reason will be stated a little farther on.)

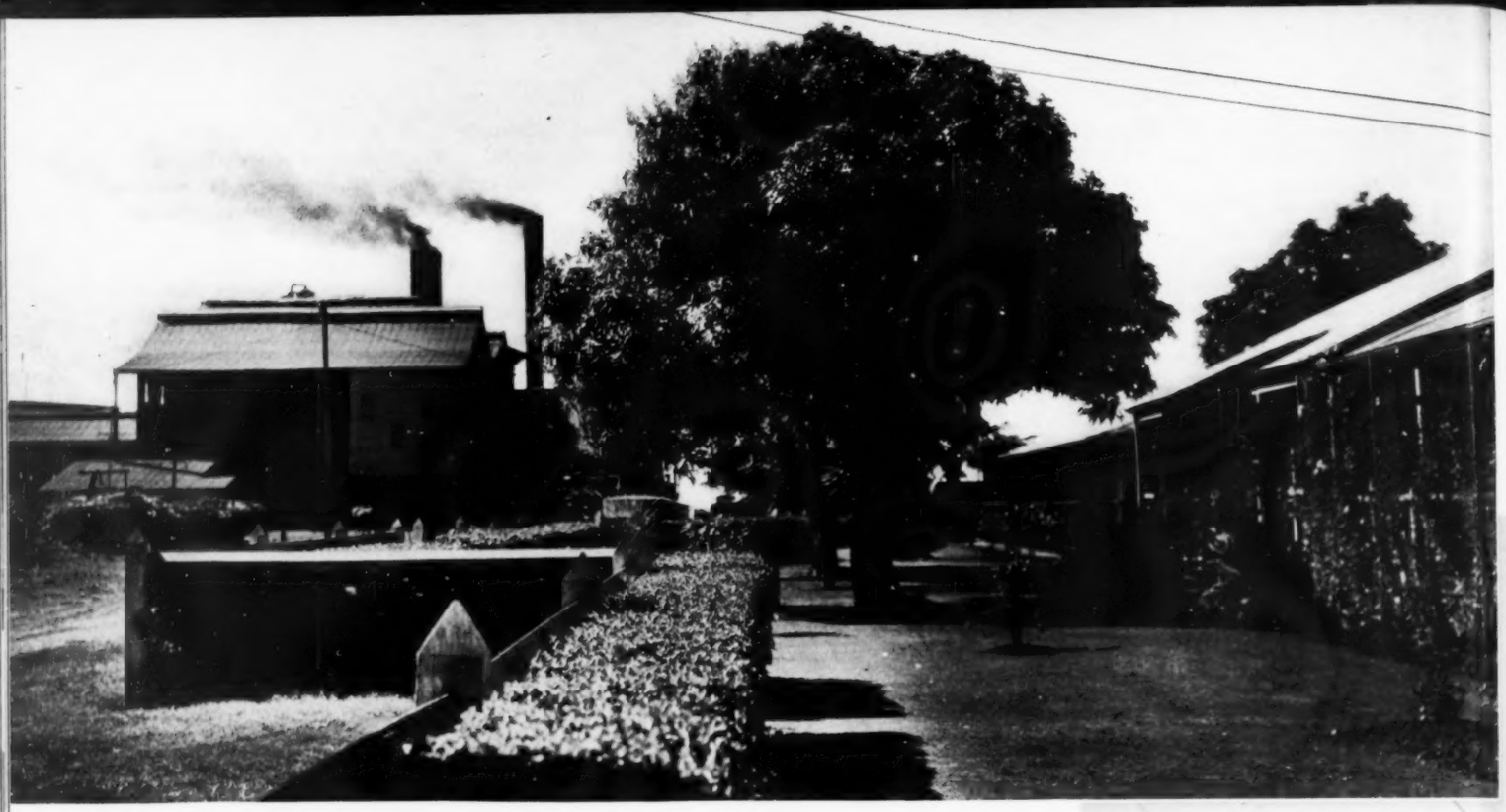
Small pumping wells are responsible for large reserves but depend for continuation on adequate prices.

After the producers in plenary conference have agreed on the distribution of production quotas and to the concessions necessary to save those whom in *laissez faire* economics are called marginal or sub-marginal enterprises, the next step in the evolution of a modern system of industrial proration, as exemplified in the world-wide sugar industry, is the setting up of administrative machinery to implement the agreement.

This machinery has taken various forms. The prevailing type is an association or central organ of the whole industry. In constituting this central organ or association of the whole, there are first formed an Association of the Primary Producers (the sugar farmers; in petroleum it would be the oilwell operators) and an Association of the Processors (Refiners). Every registered member of the industry is *ipso facto* a member of one or the other of these Associations and entitled to a vote. Each Association is headed by its own elected officers. The membership of the Central Association is composed of delegates elected in equal numbers by the two constituent Associations. From this body are elected the general officers and the managing committees, and a Central Board which represents the industry in its contacts with the public authorities. The most important function of the Central Board is to discuss the matter of fixed price with the government. Naturally, fixing of the price is preceded by a thoroughgoing examination of costs, on which is based a price structure acceptable both to the government and the industry. These prices are written into the agreement and the document is submitted to a referendum, the two wings of the industry voting separately. In case the industry ratifies it, the government also ratifies it and secures legislative enactment for it. Amendments to or revisions of the original agreement follow the same course of ratification.

It might be supposed that a nation-wide agreement among industrialists that has to run so many gauntlets will have a slim chance of getting through. But the record in the sugar industry shows the contrary. In democratic France the two wings of the industry each voted for the agreement 19 to 1. Similar majorities were returned in democratic South Africa and in democratic Germany (before Hitler); in no case has the favoring vote been less than the minimum required by the government—two-thirds of each wing. The explanation is that the great majority of men in a saturated industry are at bottom square dealers, and want stability and security for themselves and others; they will jump at a plan that is obviously fair and sound. And it is also worth noting that the same fairness that appeases the great majority of the industry has gone a long way toward appeasing the publics.

Early days of the oil industry were marked by violent fluctuations in volume of production.



The oil refinery like the sugar central, the oilfield like the cane field, can be reduced to orderly and controlled production by cooperation within the industry.

The two main committees of the prorated industry that execute the agreement are the Committee on Quotas and the Central Sales Agency.

The Committee on Quotas superintends the allocation of production allotments under the general rule that each charter member of the industry is entitled to share in the business in proportion to his peak (or potential) production. In some cases the allocations are first made on a regional basis and then distributed by an elective regional committee. Provision is made for appeals. One function of the Quota Committee is to reallocate quotas in case a producer or a region is unable to fill the assigned quota.

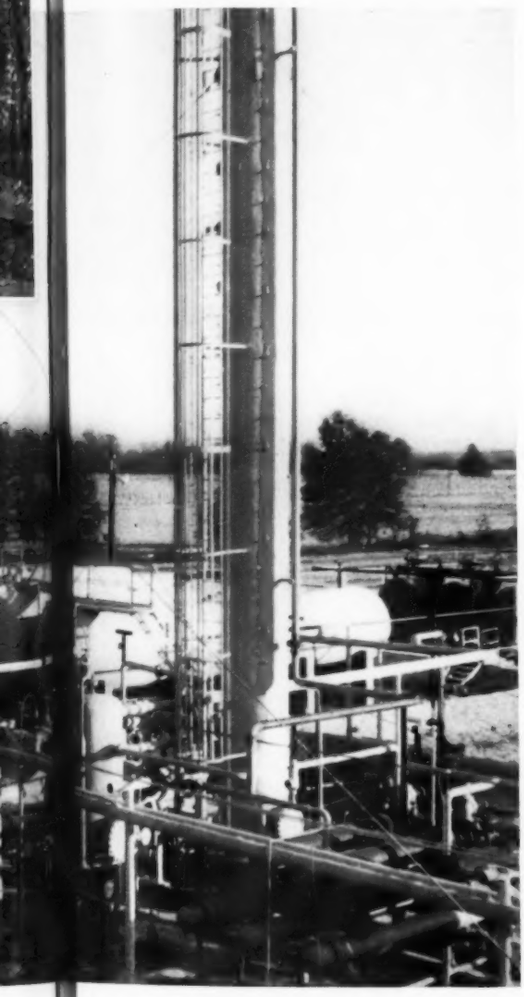
The most important, or at any rate the most conspicuous organ of a modern system of industrial proration is the Central Sales Agency. From his observations of the operations of Central Sales Agencies in various prorated sugar producing countries this writer has come to regard the invention of this institution as one of the most, if not the most, significant innovation that has appeared in economics since the advent of the industrial revolution, or the machine age. What these institutions have done for their prorated industries and for the public makes a remarkable record which is mostly beyond the immediate scope of this outline.

A Central Sales Agency is the logical capstone of every system of industrial proration that is thought out to the end. Why prorate at all? It is to give every man his share of the business of a saturated industry. What would happen if the business were not divided? The producers in a saturated industry would engage in unrestrained competition; every man would try to place his own goods ahead of his rivals, the market would be overflown with supplies, the price would fall to uneconomic levels, marginal enterprises would be extinguished; capital and jobs would be lost. To avoid these disasters the obvious first step is to limit production to an amount not in excess of consumption. And if the measures taken to balance production and consumption are not wholly effective, no system of proration will have much to recommend it. The one and only way to secure an absolute balance between production and consumption is to lodge control of the entire supply in a single hand, and this absolute control of the whole supply is the distinguishing mark of a complete modern system of industrial proration. In the sugar industry, which has taken the lead in this remarkable development in social-economics, this control is effected as follows:

The Central Sales Agency, which is composed of members democratically elected by the producing and processing wings of the industry and by consuming interests, together with a Chairman appointed by the government to represent the public, becomes invested with full title to the product as soon as it is ready to be moved in commerce. In the sugar industry the Agency owns the sugar when it is turned out at the raw sugar factory (in petroleum, ownership would begin when the crude oil is ready for the pipeline or other conveyance). In any case the original producer (who has his quota) is given an interim payment; the Agency transports the raw material at its own cost to a refinery (which also has its quota). It is to be noted that the refinery does not own either the incoming raw material or the outgoing finished product; its business is simply to process the material according to specifications at an established rate of compensation, or refiner's toll. The Agency again takes charge of the product and ships it, at its own expense, to the wholesale distributors f.o.b. station consignee; the

wholesalers pass it on to the retailers, who serve it to the public at the one fixed price that is the same at all points in the country within five miles of a freight station. Like the refiners, the wholesalers and the retailers have their fixed rate of compensation or margin for their profit.

The Agency's control of the product is absolute at every stage. In the case of sugar a record is kept of the amount of sugar in the raw material (beets or cane) delivered to the raw sugar factories by the farmers, and the factory has to account for every pound of it; the refinery also has to account for all the product it handles.



In petroleum the product of every oil well would be metered to the pipeline. The pipeline company functioning solely as a transport agency would account for every barrel of oil it transports; the refinery would account for every barrel received. Thus the Central Sales Agency, being the only buyer from the primary producers and the only seller of finish product to the consumers, would and does have absolute control at all points. In fully prorated sugar industries no opening is left for bootlegging; in petroleum there could be no such thing as hot oil.

The Central Sales Agency functions as a trustee whose business it is to see that the public is supplied with all the finished product it will take at the fixed price that has been agreed on in consultation between the government and the industry; the price is written into the law and is periodically revised by the same consultative process. At stated intervals the Agency makes up its accounts as follows:

Total product sold for all producers	X tons
Total cash received from all consumers	Y dollars
Total Agency expense	Z dollars
Net proceeds,	Y-Z = M dollars
Net income per ton,	M/X = N dollars

The quantity N dollars is the net payment per ton which the primary producer receives for what he has delivered.

The total Agency expense (Z dollars) includes:

(1) Transportation costs from the points of origin of the raw material to the refining points, and freight costs from the refining to the consuming points.
(2) The fixed refiner's toll.
(3) The fixed margins for the distributors.
(4) Clerical hire, office expense, insurance and other administrative expense.
(5) Field expense (inspection) in exercising the necessary control at producing and refining points.
(6) Contributions to the revolving fund for modernization of inefficient producing installations.
(7) Price differentials paid to alleviate cases of special hardships.
(8) Local, State and National taxes.
(9) Subsidies voted by the industry in support of scientific and technological research, and
(10) Subsidies granted by agreement between the government and the industry to collateral industries and to special categories of consumers (of which more will be said later), all of which are included in the fixed retail price.

The Agency maintains no high-pressure sales organization. Its products are all standardized and hence of uniform quality; there is consequently no expensive competitive advertising, which is limited to appeals intended to increase the total volume of consumption rather than in favor of numerous different brands that are all essentially alike.

An organization operating on these lines is able to reduce distributing costs to an absolute minimum, and is therefore able to save a great deal for both the public and the producers. As has already been said, one of the reasons why the fixed retail price for the product of a completely prorated industry can be kept low is that the producers, whose market is now stabilized and practically free from serious risk, are content with a rate of profit which does not have to be surcharged in order that contingent losses may be written off. The other reason is the greatly simplified and greatly cheapened distribution process. The combined result is that under complete proration the industry is able to carry on with greater assurance than before, to take care of all its weaker elements, and to lend very effective support to other departments of the national household, at an overall cost to the public that is at most no greater than before.

There is one feature of the operations of the Central Sales Agency of a fully prorated industry that deserves especial notice. This is the fact that the Agency bears all the expense of transporting the raw material to the refineries, and from the refineries to market. No primary producer and no processor or distributor, no matter where he may be located, pays any freight bills on his product. Freight costs and all other Agency disbursements come out of the one general fund created by the fixed retail price that is paid by the public. The transportation companies of course hold to their well established ton-mile basis of freight charges, but the Agency simply absorbs it all and disposes of it as a general expense, chargeable against the product of the industry as a whole.

The more the writer has observed the operation of this method of handling the economics of transportation in various sugar-producing countries the more he is inclined to regard it as a social-economic invention of first importance. On the one hand it abolishes all locational differentials between different regions as well as between individuals engaged in production; and on the other hand it abolishes similar differentials between consuming regions and consuming individuals. In the one case it completely levels the values of all industrial properties in so far as these values depend on nearness to or remoteness from market. Under the prevailing system, where the cost of transporting raw materials or finished goods is graded according to the distance traversed, remotely located producers or whole regions are penalized to an extent that may exclude them from the industry; and for the same reason consumers in remote regions find their cost of living raised. The possessors of industrial property or sources of raw materials located near large consuming centers have all the advantage, and this advantage of location may have a high money value. One would naturally expect that the owners of a favorably situated enterprise would hesitate to consent to an arrangement that would depreciate this value. But this is only another one of the concessions that the strong elements of prorated national sugar industries have made to their weaker colleagues.

Again it may be remarked that this and all other concessions that have entered into proration agreements are not exclusively based on altruism; the big fellows have never forgotten that they want to live, too. What they as well as the little fellows have been after is stability and assured security; and this ironing out of transportation differentials has played an important part in securing the ratification of such agreements by both wings of the industry, and by the governmental and legislative authorities.

In the third and concluding section of this article the writer will give his ideas of how a modern (complete) system of industrial proration might be fitted on the petroleum industry of the United States. In some details the proposed system might vary from the system now to be seen in the world-wide sugar industry, but the fundamental principles would be the same.

Foreign Oil Legion

Armando d'Almeida

MR. ARMANDO D'ALMEIDA arrived in this country from Rio de Janeiro at the end of July for a short stay. A well known Brazilian business man, he has for years been a firm believer in the necessity of Brazil's adopting American industrial methods and inviting American experts to cooperate in the exploitation of the immense potential mineral wealth in the soil of Brazil. On his trip to the United States two years ago, Mr. d'Almeida met Mr. Herbert Hoover, Jr., president of the United Geophysical Company of Pasadena, California; so impressed was he by the United Geophysical Company's methods of research in locating oil, which Mr. Hoover described to him, that, on his return to Rio, he communicated to General Horta Barbosa, president of the government organ, the Conselho Nacional de Petroleo, the manifest advantages of prospecting for oil in Brazil by this means. After lengthy negotiations, Mr. d'Almeida was successful in arranging for a contract to be signed by the Conselho Nacional de Petroleo and the United Geophysical Company. Mr. d'Almeida was appointed United's representative in Brazil, and has been responsible for all arrangements in connection with sending the first United crews to Brazil, as well as seeing to it that they are supplied with everything needed to carry out the work. The contract with United Geophysical was renewed this June.

Above, Morgan Walker of Standard Oil Company of N. J. and Standard of Venezuela as he sailed from New York for Venezuela on July 11.

Chester Crebbs, president of Mene Grande (Gulf) sailing from New York for his Caracas headquarters on July 11 accompanied by Mrs. Crebbs and their son Robert.

Above, Sir William Garthwaite, director, British Controlled Oilfields, Ltd., arriving in New York for an indefinite stay on July 14. Below, J. S. Holt of Consolidated Oil Company sailing from New York for Venezuela for a two year stay.

F. G. Rappaport, general manager, British Controlled Oilfields, Ltd., of Maracaibo in center of picture. Mr. Rappaport sailed on July 11 for Venezuela and is shown as he was seen off, (L. to R.) by W. J. Molloy and E. T. Landgraff at left and Ted Carter and M. E. Nicklin at right.

F. J. Jobst seeing off V. P. Yocom, Standard of Venezuela in New York harbor on July 11.

Above, Mrs. William H. Wilgus sails from New York on the Santa Paula to rejoin her husband who is instrument engineer for Lago at Aruba. Below, H. G. Kieswetter, U. S. Rubber Company leaving New York for Bogota on July 18.

Mr. Roger Knight, Oil Well Supply Company's well-known and popular representative in Buenos Aires, has sailed for England to join the British Forces. Mr. Knight, who is of British parentage, has spent a large part of his life in the Argentine, where, together with Brazil and adjacent territory, he has looked after the interests of the Oil Well Supply Company for considerable time.

Above, J. C. Case of Socony-Vacuum sailing from New York on June 20 for a business trip through South America.

Above, Willard Hall, in charge of industrial relations for Standard Oil Co. of N. J. sailing from New York on the Santa Rosa for a two year business trip in South America.

Photographs on this and the facing page taken by Cosmo-Sileo

Above, Harry A. Jarvis, Cia. Nativa de Petroleo of Argentina sailing from New York for Buenos Aires with Mrs. Jarvis on July 3. Below, F. W. Floyd of Standard of Venezuela sailing from New York on July 11 with Mrs. Floyd and their niece, Miss Virginia Groves.

Below, Robert Milbrath, Standard of Venezuela arriving on June 30 in New York with Mrs. Milbrath for a vacation in Wisconsin.

WORLD OIL PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries.

U. S. BARRELS METRIC TONS

	June 1941 Preliminary	June 1940	Jan.-June 1941	Jan.-June 1940	June 1941 Preliminary	June 1940	Jan.-June 1941	Jan.-June 1940
United States	115,081,500	111,690,000	667,394,400	687,903,500	15,570,491	15,111,622	90,298,253	93,073,181
Soviet Union	21,870,000	21,141,000	131,220,000	118,098,000	3,000,000	2,900,000	18,000,000	16,200,000
Venezuela	18,925,350	18,629,609	100,696,184	98,162,773	2,810,000	2,766,089	14,951,178	14,575,022
Iran	6,500,000	6,449,520	38,843,284	39,127,171	862,253	855,540	5,121,853	5,190,340
Netherland India: Sumatra	3,400,000	3,345,120	20,095,000	20,293,738	435,283	426,270	2,570,710	2,586,081
Borneo	1,200,000	1,070,400	6,570,400	6,493,839	153,629	137,040	841,133	831,462
Java	575,000	537,660	3,237,600	3,261,898	73,614	69,210	414,865	417,944
Molucca and other	60,000	60,300	353,800	365,926	7,681	7,710	45,401	46,825
Rumania	3,392,500	3,682,618	19,597,867	22,413,843	460,000	499,338	2,657,338	3,039,165
Mexico	2,895,000	3,873,720	17,722,000	20,247,787	425,110	491,923	2,602,347	2,896,701
Iraq	600,000	2,559,060	5,100,000	15,525,007	80,203	342,330	681,725	2,076,862
Colombia	2,000,000	2,276,000	10,595,000	13,639,890	278,940	317,433	1,477,684	1,902,352
Trinidad	1,750,000	1,659,000	10,525,000	9,674,568	246,132	233,300	1,480,309	1,360,623
Argentine	1,800,000	1,677,338	10,722,492	9,874,795	256,410	238,937	1,527,424	1,406,664
Peru	1,110,000	1,106,580	6,110,000	6,713,284	146,534	146,400	806,599	888,211
Bahrein	608,000	602,560	3,629,000	3,647,288	82,969	82,227	495,220	497,864
Burma	650,000	657,600	3,908,040	3,938,405	89,779	90,510	539,455	543,209
Canada	840,000	657,098	4,894,969	3,681,029	106,897	83,621	622,835	468,441
Brunei	460,000	472,200	2,783,313	2,864,694	61,365	62,970	371,305	382,050
Great Germany: Old Reich	370,000	371,790	2,232,622	2,255,588	52,910	53,700	319,265	325,890
Ostmark	55,000	59,220	346,959	359,306	8,199	9,390	51,722	57,079
Slovakia and Moravia	8,000	9,780	55,100	59,363	1,178	1,470	8,170	8,918
Poland	300,000	320,730	1,861,400	1,945,814	40,436	43,020	250,892	261,076
Japan	220,000	217,470	1,312,000	1,319,326	31,294	31,050	186,624	188,487
British India	188,240	185,430	1,117,856	1,125,013	26,000	25,590	154,400	155,320
Ecuador	162,622	201,650	765,641	1,227,306	21,439	26,585	100,938	161,804
Saudi Arabia	470,000	356,571	2,813,700	2,588,938	64,000	48,304	382,200	350,715
Sarawak	108,000	108,660	648,000	659,221	13,802	13,980	82,812	84,843
Egypt	625,000	465,000	3,800,000	2,733,367	89,260	66,409	542,699	390,367
Italian Empire: Albania	110,000	117,330	700,000	711,820	16,486	17,790	104,914	106,500
Italy	3,800	4,400	23,364	32,550	472	540	2,908	4,030
France	40,000	41,100	234,922	249,458	5,610	5,760	32,949	34,944
Hungary	210,000	150,000	1,145,000	705,000	28,252	20,180	154,041	94,830
Bolivia	10,000	9,500	61,106	51,928	1,309	1,166	8,048	6,030
Other Countries	48,000	47,790	287,200	290,031	6,875	6,810	40,950	41,319
WORLD TOTAL	186,646,012	184,813,804	1,081,403,219	1,102,241,464	25,554,812	25,234,214	147,929,166	150,655,149

Official Crude Oil Production Figures from 1938 to 1940

	Daily Averages Bbl.		Daily Averages Metric Tons		Bbl.			Metric Tons		
	Jan.-June 1941	Jan.-June 1940	Jan.-June 1941	Jan.-June 1940	1940	1939	1938	1940	1939	1938
United States	3,667,002	3,779,689	496,144	511,391	1,351,849,500	1,264,962,000	1,214,355,000	182,904,869	171,152,192	164,346,325
Soviet Union	724,972	648,890	99,447	89,010	249,318,000	216,727,024	206,192,000	34,200,000	29,530,168	28,859,000
Venezuela	556,332	539,355	82,603	80,082	184,761,241	205,783,650	188,429,050	27,432,998	30,533,706	27,845,286
Iran	214,603	214,984	28,297	28,518	79,151,675	78,151,332	78,320,840	10,443,546	10,367,117	10,358,495
Netherland India: Sumatra	111,022	111,505	14,202	14,209	40,685,226	41,557,013	34,538,128	5,208,709	5,320,320	4,662,836
Borneo	36,300	35,680	4,647	4,568	14,006,279	13,125,425	12,812,383	1,793,148	1,680,377	1,719,783
Java	17,887	17,922	2,292	2,296	6,557,295	6,568,714	6,955,283	839,495	842,237	933,595
Molucca and Other	1,954	2,010	250	257	762,674	836,144	607,622	97,641	107,047	81,560
Rumania	108,275	123,152	14,681	16,698	42,885,625	46,020,000	48,366,000	5,815,000	6,240,000	6,603,000
Mexico	97,911	111,251	14,377	15,915	40,000,000	39,428,141	38,505,824	5,873,715	5,794,035	5,716,423
Iraq	28,176	85,302	3,766	11,411	24,225,007	30,791,132	32,404,000	3,238,878	4,115,845	4,345,000
Colombia	58,535	74,944	8,164	10,452	25,592,890	23,857,000	21,581,588	3,569,434	3,327,336	3,007,935
Trinidad	58,149	53,156	8,178	7,475	20,218,568	19,270,256	17,736,176	2,842,918	2,710,515	2,472,943
Argentine	59,240	54,257	8,991	7,728	20,616,928	18,738,003	17,076,237	2,936,880	2,657,232	2,432,857
Peru	33,756	36,886	4,456	4,880	12,985,284	13,587,906	15,908,279	1,716,195	1,798,557	9,099,885
Bahrein	20,049	20,040	2,736	2,735	7,096,141	7,588,554	8,297,998	968,502	1,045,391	1,130,734
Burma	21,591	21,639	2,980	2,984	7,737,902	7,872,981	7,499,498	1,098,184	1,087,424	1,039,960
Canada	27,044	20,225	3,441	2,573	8,718,053	7,837,503	6,965,457	1,109,440	997,487	879,921
Brunei	15,377	15,740	2,052	2,099	5,729,374	5,767,227	5,387,214	764,006	768,320	707,123
Great Germany: Old Reich	12,335	12,393	1,763	1,790	4,543,954	4,487,491	3,850,044	653,590	647,337	552,074
Ostmark	1,916	1,974	285	313	718,494	693,247	370,038	114,045	109,904	63,468
Slovakia and Moravia	304	326	45	49	118,775	119,380	132,005	17,836	18,103	19,282
Poland	10,284	10,691	1,386	1,434	3,891,456	3,898,044	3,828,438	521,984	522,874	504,678
Japan	7,248	7,249	1,031	1,035	2,638,644	2,652,930	2,511,184	376,657	379,161	356,328
British India	6,176	6,181	853	853	2,249,835	2,332,467	2,330,209	310,596	322,160	322,125
Ecuador	4,230	6,743	557	889	2,349,015	2,312,118	2,257,278	309,686	306,824	319,877
Saudi Arabia	15,545	14,224	2,111	1,927	5,364,610	3,933,904	495,135	726,785	536,366	66,683
Sarawak	3,580	3,622	457	466	1,317,185	1,329,645	1,624,882	168,475	171,322	200,126
Egypt	20,994	15,018	2,998	2,144	6,053,367	4,603,797	1,561,231	864,514	657,570	223,058
Italian Empire: Albania	3,867	3,911	579	585	1,497,124	1,393,727	437,597	224,199	208,279	65,313
Italy	129	178	16	23	57,350	91,330	106,083	7,110	11,346	13,178
France	1,297	1,370	182	192	496,420	500,815	516,240	69,578	70,478	72,106
Hungary	6,325	3,873	851	521	1,755,000	815,248	330,829	236,025	109,896	42,798
Bolivia	343	285	45	32	110,484	100,885	106,620	14,249	11,998	13,262
Other Countries	1,586	1,593	226	227	579,997	578,036	243,000	82,779	82,300	34,080
WORLD TOTAL	5,974,603	6,056,272	817,288	827,775	2,176,639,372	2,078,313,069	1,982,639,390	297,551,666	284,241,224	279,111,097

Detailed monthly reports were published in February, 1941 issue.

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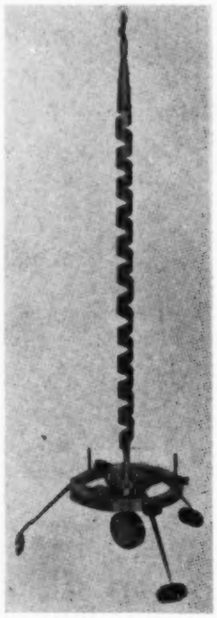
GEOPHYSICS

The Gulf Gravimeter—R. D. Wyckoff, in GEOPHYSICS, Vol. 6 (1941), No. 1, pp. 13-33.

After much consideration and experimentation, an unastatized type of instrument was finally selected for commercial development. The unique feature of the instrument is a helical ribbon spring (see figure) supporting a moving mass with no ligaments, levers or other attachments. This spring produces a rotation of about 1 second of arc per 10^{-7} change in gravity, which is observed by means of an attached mirror and a micrometer microscope.



Since 1936 more than 200,000 stations have been observed by the Gulf gravimeters, and statistics on these routine data indicate that the probable error of a single observation is a little less than 0.05 milligal. For example, a set of data obtained at Kuwait, Arabia, where the operator repeated certain stations twenty or thirty times during several months, shows 0.04 mg. as the probable error of a single observation and the distribution follows a typical probability curve. These operations were under rather adverse conditions. Other examples taken at random from routine field data but under more favorable circumstances show for instance that repeat observations involving two different instruments on a group of 15 or 20 stations resulted in a maximum difference of 0.1 mg., a mean deviation of 0.04 mg., and a probable error of a single observation of 0.02 mg. A second group of stations showed a maximum difference between observations of 0.08 mg., a mean deviation of 0.03 mg., and a probable error of 0.02 mg.

It is of interest to note that the accuracy of gravimeters is sufficient to permit their use in obaining gradient values comparable in accuracy to the torsion balance. Thus an array of three gravimeter stations forming a right angle with legs only 300 feet in length if observed with a readily obtained prevision of 0.02 mg. will provide a gradient measurement equal in accuracy to that obtainable with the torsion balance having a probable error of 4ϵ.

DRILLING

Measuring Particle-Size Distribution and Colloid Content of Oil-Well Drilling Fluids — George L. Gates, in BUREAU OF MINES REPORT OF INVESTIGATIONS 3549 (1941).

This research grew out of an impression (gained from the literature of the subject) that the oil industry was not measuring the particle-size distribution of its drilling muds. This property of mud-fluids is of distinct importance because the value of such fluids largely depends on their content of particles of colloid dimensions, that is, the very smallest particles, which are extremely important as a desirable constituent of mud fluids for well drilling. Without colloids, the solids in a mud fluid would settle rapidly and the sealing and the wall building qualities of the fluid would be greatly impaired. Mud fluids with insufficient quantities of colloids also are lacking in "lubricating" qualities, and it is difficult to "run casing" in bore holes drilled with such fluids.

This being the case, mud engineers will doubtless appreciate a practicable method for classifying and checking up on clays and other mud-building materials on the basis of particle-size distribution, with special reference to particles of colloid dimensions. As a foundation for his method the author takes the hydrometer method already in use by ceramic engineers for investigating clay slurries, and modifies it for the purposes of the oil-field mud engineer. In this method, the mud is stirred up and allowed to settle; by means of a hydrometer the specific gravity of the suspension is measured at different times and depths. This data, together with a measurement of the viscosity of the suspension, gives all the facts needed for figuring the colloid content of the sample. Full details of theory and procedure are given.

Side-Wall Coring in the Gulf Coast Area —H. L. Flood, in PETROLEUM ENGINEER, Vol. 12 (1941), No. 6, pp. 156-158.

Reference is made to the practice of a drilling contractor who has come to rely almost entirely on side-wall coring devices to procure core data in all wells drilled, including two that were 11,900 feet deep. That is, instead of taking cores in the conventional manner from the area of the hole itself and then using side-wall coring devices to fill in gaps that were overlooked in the conventional method, he follows this method: The well is drilled "full hole" without stopping for conventional coring; when the hole is completed an electrical log is taken, and on the findings thereof is based a decision concerning the number and location of side-wall cores to be taken, using equipment now available for the purpose.

The reasons that are said to justify this procedure are, first, by omitting conventional coring the number of days required to drill a given well is reduced, which may mean a saving of hundreds or even thousands of dollars. Much of this time and money saving is possible because the electrical log gives a definite picture of the well as a whole and indicates where it is necessary or unnecessary to core. Not only will the number of unnecessary cores be reduced, but the cores will be taken for a definite purpose as indicated by the log.

Then again, hours of time are saved and expensive delays avoided in the work of analyzing the cores. Instead of maintaining a field core laboratory for the duration of drilling, such a laboratory may be engaged to run the entire set of cores at the well without delay, the sidewall cores being then taken in one continuous operation after completion of the well. Not only are the cores fresh and uncontaminated, but they quickly show the point where casing is to be set, and the casing crew can go to work within a few hours after the last core is taken.

However, the present methods of side-wall coring run into difficulty with very hard formations, but inventors are at work perfecting an electric motor-driven sampler that will mill out the hardest rock.

OPERATION

The Use of Depth-Pressure Data in Determination of Well Potentials in California—Richard W. French and Collaborators, before DIVISION OF PRODUCTION, A. P. I., 11th Mid-Year meeting, Tulsa, May, 1941.

Well potentials for use as the primary factor in allocation under the California "uniform method" are being established successfully by depth pressure means in flowing, gas lift and pumping wells. Some operators are doubtful of the accuracy of the method, and being unfamiliar with the measurement and application of sub-surface pressures have viewed the procedure with misgivings. However, official tests have fairly established its reliability.

In addition to minimizing overproduction resulting from an open-production test, several other advantages accrue to an operator using the sub-surface-pressure method of potential determination. Primarily, the operator does not risk the damage which may result to the well or reservoir from capacity well production. The dangers of water incursion and sand entry resulting from excessive production rate are well known. Elimination of high test rates permits installation of smaller production equipment. This includes lease storage and shipping facilities, gas traps and surface lines, surface pumping equipment, sucker rods, pumps, and ofttimes tubing. The current trend in California curtailment toward progressively smaller allotment for a given well potential accentuates the need for a minimum capital outlay in production equipment. The measurement of well-performance characteristics, obtained during the determination of well potentials, furnishes valuable information to the operator. Production problems are simplified through a better understanding of the ability of the

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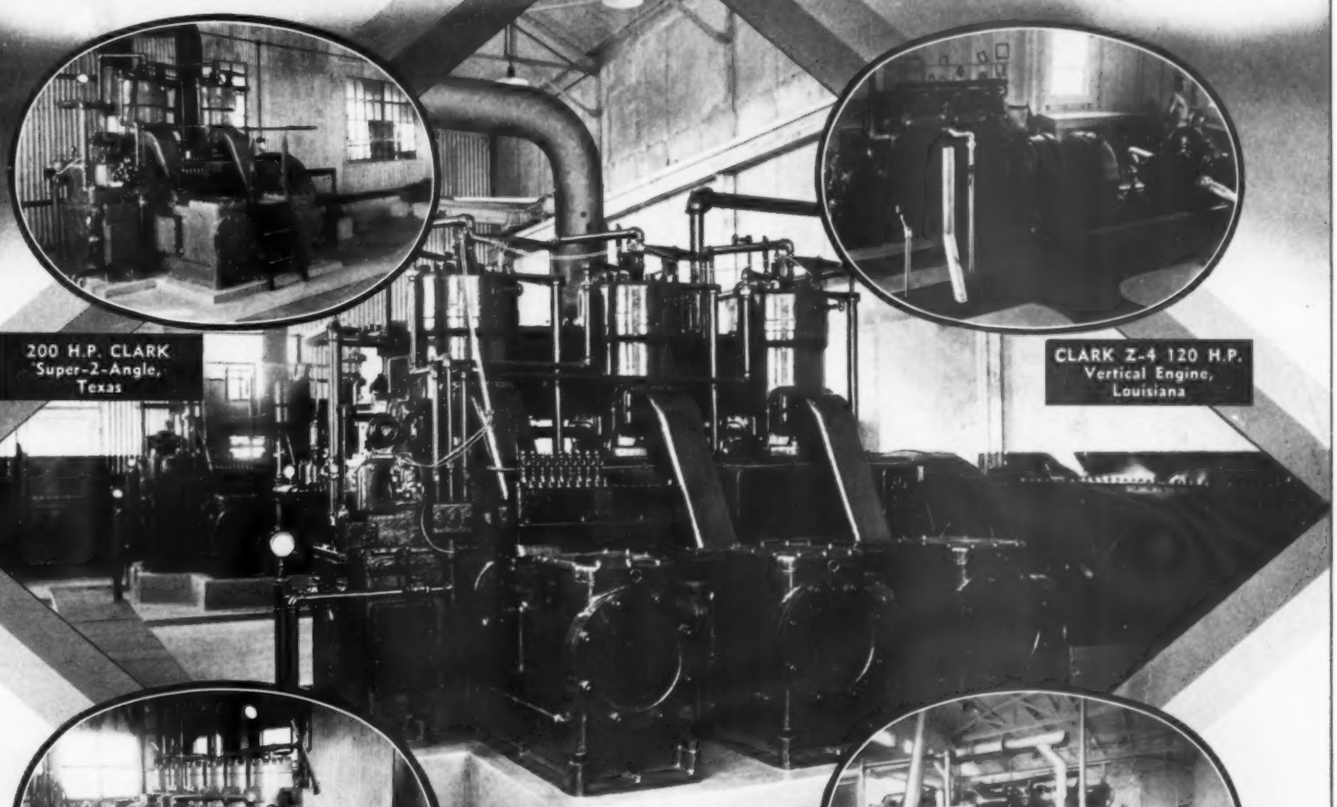

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well to produce, and production equipment may be better fitted to the well. By following the trend of sub-surface pressure with time, a long-range planning system for well-equipment needs may be instituted. Useful data for reserve estimation are provided, and the effect of withdrawals from the reservoir may be studied.

Determining Potentials by Drawdown Methods —Chas. Rodd, before A. P. I. MID-CONTINENT DISTRICT, DIVISION OF PRODUCTION, Amarillo, March, 1941.

During the past two years the drawdown method of determining well potentials has largely supplanted the physical method of testing wells previously used in Kansas.

The term "drawdown" derives from the fact that this type of test necessitates the determination of the reduction or "drawdown" of bottom hole pressure, or fluid level, of a well at one or more stable rates of production. When the "drawdown" of a well is directly proportional to the liquid production, the pressure-flow relationship may be expressed quantitatively by a constant which is commonly referred to as the productivity index of the well. Depending upon the method of testing and the instruments used, the productivity index may be expressed in barrels per day per pound reduction in bottom hole pressure, or barrels per day per foot drawdown.

The author disclaims any desire to arouse any controversy regarding whether or not a straight-line relation between production and pressure exists in all wells, or in any extremely large well to the point of zero bottom hole pressure. Several thousand wells in Kansas have been tested by the drawdown method. In all but a few of the tests the relationship between pressure and fluid production was approximately a straight-line function between the limits of production required under Kansas proration rules. Numerous wells, with fluid capacities ranging up to 2000 barrels per day, were tested to near capacity without deviating from the straight-line relationship.

In general, drawdown tests, determined by fluid levels alone, have been wholly satisfactory on wells where little or no gas is present and where the density of the annular fluid remains constant. The use of the method has permitted substantial reduction in the cost of equipping wells to pump, and has eliminated the necessity for excessively high rates of production during potential tests, which rates were, in the opinion of most operators, conducive to water encroachment.

Some skepticism, as well as criticism, has been expressed because of the extremely high well capacities frequently reflected by the drawdown method. In defense of the method and those who have sponsored and endorsed it, it should be stated that no claim was ever made regarding the accuracy of straight line extrapolation of drawdown data beyond approximately 3000 barrels per day. The maximum potential of 3000 barrels was selected primarily because this was the approximate top limit to which the method could be compared to physical data.

NATURAL GAS

Dehydration of Natural Gas and Absorption Oil —C. S. Worley and Dean E. Foster, in REFINER, Vol. 12 (1941), No. 8, pp. 46; 48; 51.

This paper discusses the more or less conventional process of dehydrating natural gas to a dew point of about 30°F. by means of diethylene glycol; it has now been found necessary or at least advisable to pay some attention to the absorber oil in the natural gasoline plant through which the gas passes after being dehydrated with diethylene glycol. In the normal operation of an oil absorption plant using the steam distillation process, the absorption oil retains a small amount of condensed steam, which rehydrates the once-dried gas. To get around this the authors describe a process which has been used by two companies but which does not seem to have been published. This device consists in bubbling a small amount of gas through the hot lean oil just after it has left the still, using a simple equipment the chief components of which are a bubble tower and a condenser to remove the water and oil that the gas has picked up. The gas used for drying the absorption oil is stabilizer waste or fuel gas on its way to the power plant.

Cathodic Protection Against Corrosion of Gas-Well Casing—Wm. E. Huddleston, before NATURAL GAS SECTION, AMERICAN GAS ASSOCIATION, Dallas meeting, May, 1941.

Cathodic protection against corrosion was first applied to pipe line systems and is now being extended to many other items of equipment in the petroleum industry, including oil tank bottoms, refinery equipment, etc.

The author here records an application of cathodic protection to a 1000 ft. string of casing in a 6¼ in. gas well. For obtaining the necessary data, a method of making an electrical survey of conditions was worked out. In the end it was ascertained that to protect this particular casing would require a 6.04 ampere load and an operating voltage of 3 volts to

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overcome an overall resistance of about 0.50 ohm; the required total power input to the cathode circuit was 18 watts. For comparison, the power input in cathode protection of pipe lines ranges between 3.6 and 72 watts. Naturally, casing strings longer than 1000 feet will require more power, even if other conditions remain the same. In this particular case corrosion was reduced approximately 90 per cent.

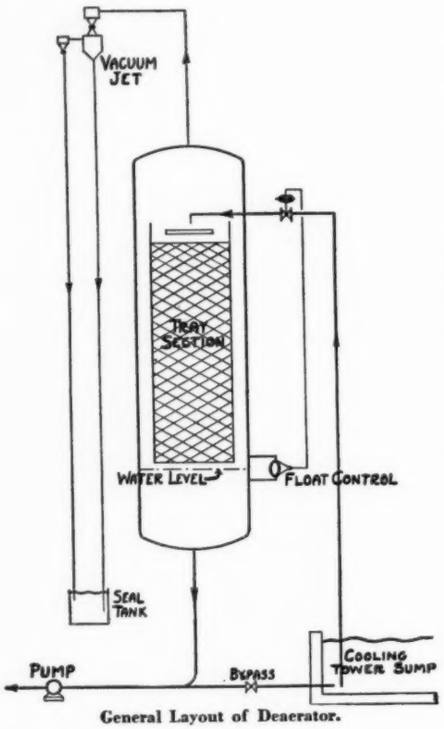
Experience to date indicates that corrosion of gas well casing can be mitigated sufficiently to add several years to its useful life, provided that cathodic protection is installed before the casing wall has reached penetration or near penetration. Obviously, the most satisfactory practice would be to insulate new gas wells as they are completed.

REFINING

Use of the Deaerator in Preventing Corrosion on the Water Side of Refinery Equipment—W. H. Atwill before AMERICAN PETROLEUM INSTITUTE, Tulsa Meeting, May, 1941.

Experience shows that, in a corrosive water that is normally alkaline, dissolved oxygen is the main factor in corrosion. Eliminate the dissolved oxygen and you eliminate the corrosion, whether it be the dezincification-type corrosion of admiralty condenser tubes, the pit-type corrosion of red brass tubes and steel pipe, or the general corrosion of cast iron.

Two years ago The Texas Company, in an attempt to reduce cooling-water corrosion, installed a mechanical deaerator on one of the recirculated cooling-tower systems at its Port Arthur, Texas, refinery. This deaerator is installed on a recirculated system utilizing a forced-draft type of cooling tower, with a circulating rate of 1,500 gal. per min. All the waters available in this area are normally corrosive non-scale-forming waters. The makeup water to this particular system is of low chloride low hardness content, and gives a pH of 8.0 to 8.5 when concentrated in the cooling tower.



General Layout of Deaerator.

The general arrangement of the deaerator is shown in the accompanying sketch. The cold water from the cooling-tower sump is drawn into the 6-ft. x 20-ft. deaerator tower by the high vacuum maintained by a 2-stage vacuum jet. A diaphragm-operated inlet valve regulates the flow of water to hold a level just below the tray section. As the water passes down through the tray section, it continually is broken up into films or sheets, exposing as much water surface as possible to the high vacuum. Under these conditions, most of the oxygen is released from the water and is drawn out through the vacuum jet. A single-stage centrifugal pump takes suction on the bottom of the deaerator tower and discharges to the refining unit.

Installation cost of the 1,500-gal.-per-min. deaerator was $8,100; and operating costs—including vacuum-jet steam, jet condenser water, and increased cost of pumping cooling water to the refining unit—have averaged $50 a month. In two years' time, the deaerator has more than paid for both its installation and operating cost by reduction in condenser-tube corrosion alone. In addition, the deaerator has resulted in lower pressure drop and reduced repair costs of water-supply lines, better heat-transfer rates, fewer shutdowns, and better operation of the refining unit.

Molded Carbon in the Refinery—M. J. Dorcas, before WESTERN PETROLEUM REFINERS' ASSOCIATION, Hot Springs, April, 1941.

Carbon as a material component of refinery equipment is attracting some attention. The starting material for the production of such equipment is petroleum coke, which has the convenient property of being plastic when heated and subjected to pressure. It can thus be formed into pieces of any desired shape. The

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pieces so produced are baked at a high heat which drives off pitches and tars, and leaves a dense, solid, homogenous piece of elementary carbon that will resist practically any sort of chemical action likely to occur in oil refinery processes. It will not oxidize except at rather high temperatures. It has a very low coefficient of expansion with temperature changes and will not spall in sub-zero cold. If the molded carbon has been graphited by heating in an electric furnace, it becomes a better conductor of heat than iron.

These properties make it suitable for various uses. The chief refinery use at present is in the form of Raschig rings for tower packings, especially where refinery products are scrubbed with alkaline solutions to remove sulphur; in towers for counter-current extraction of lubrication oils, and in towers where there are rapid alterations of temperature. Even the towers used for containing the Raschig rings may be built of carbon brick, Bubble caps, trays, heat exchangers, dephlegmating coolers, surge pipes, and many other parts have been made of this material.

Corrosion Prevention on the Water Side of Refinery Equipment—W. H. Atwill, before AMERICAN PETROLEUM INSTITUTE, Tulsa, 11th Mid-Year meeting, May, 1941.

Four treatments for diminishing water corrosion of refinery equipment were tried at the Port Arthur refinery of the Texas Co. Little if any reduction of corrosion resulted from the use of sodium hydroxide or sodium silicate.

Much better results have been obtained from a chromate treatment. In mechanical-draft cooling towers a concentration of 500 ppm. of chromate—as $Na_2CR_2O_7 \cdot 2H_2O$—is maintained in the circulating water by the daily addition of sodium dichromate. Sufficient caustic is added to convert the dichromate to the normal chromate and give a pH of 8.0 in the water. Small amounts of sodium hexameta-phosphate also are added daily, so as to give a concentration of 5 to 10 ppm of total phosphate, as PO_4. Experience indicates that the metaphosphate (and the orthophosphate resulting from its conversion) tends to keep the condenser tubes and supply lines free from mineral and corrosion deposits.

As the windage loss from mechanical-draft towers is negligible, it is necessary to control the total solids concentration of the circulating water by bleeding off some of the concentrated water. This is done by continuous blowdown from the tower system, regulated to limit the sodium-chloride concentration to about 850 ppm. With a makeup water of approximately 120 ppm of sodium chloride, this allows 7 concentrations in the circulating water.

Best results from this treatment naturally are obtained with an entirely new cooling-water system; but results in an already corroded system are often more evident, because it permits a comparison with the conditions before treatment. In one of the newer cooling-tower systems that has received chromate treatment since its installation, more than 11,000 red-brass condenser tubes have been in water service for more than 18 months without any replacements; and, in a second system of more than 3,000 red-brass tubes, no failures have occurred in 26 months. Examination of the equipment shows very little corrosion in the steel and cast-iron water-supply lines and cast-iron condenser heads.

Chemical costs of the chromate treatment in mechanical-draft cooling towers have averaged about $35 per month per 1,000 gal. per min. of water circulated; but this cost is justified amply by reduction in corrosion in condenser tubes and water-supply lines, better heat-transfer rates, fewer shutdowns, and generally better operation of the refining units.

Because of the relatively high windage loss from natural-draft cooling-towers the chromate concentration has been held at 100 to 150 ppm. to reduce chemical costs. Indications are that a considerable decrease of corrosion results even from this diminished chromate concentration at a cost of about $20 per month per 1000 g.p.m. of water circulated. Tests with sodium hexametaphosphate alone have not been finished. Operators handling the sodium dichromate should avoid contact of the chemical with the skin.

Process for Converting Pennsylvania Bright Stocks into Neutrals —C. R. Wagner, in OIL & GAS JOURNAL, vol. 39 (1940), No. 32, p. 14.

The tendency in the lubrication of automotive vehicles is toward lower-viscosity lubricants, which has shifted demand in favor of neutral oils at the expense of bright stocks Formerly the proportion was about 60 bright stock and 40 neutrals; now the ratio is about the reverse, i.e., 60 neutrals and 40 bright stock. The price of bright stock has declined and that of neutral oil has increased and this calls for a process of converting bright stock to neutral.

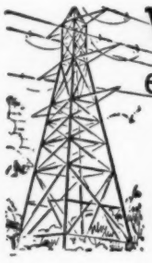
The process recommended is to blend 15-pour bright stock with 10 per cent light oil (kerosene) and charge to a shell still. Use of bright-stock solution eliminates blending. At the 35-40 viscosity point the overhead stream (approx. 525-550 deg. F.) is cut to 180 stock storage. Steam and firing are controlled to maintain the viscosity of the overhead at 90-100 at 100 deg. F. The aim is to take overhead about 93-96 per cent of the original bright stock charge (700-720 deg. F.). The bottoms may be mixed with a light oil and reprocessed.

The 180 stock is then blended with normal Pennsylvania pressed oil or 85 stock or both, The proportion of each component is more or less immaterial although it is preferable not to use more than 30 per cent of 180 stock from bright-stock conversion in the mix. The blend is then reduced in the normal manner for reducing pressed oil to 180 distillate.

Reactions of Hydrocarbons in Electrical Discharges—Charles L. Thomas, Gustavav Egloff and J. C. Morrell, in CHEMICAL REVIEWS, vol. 28 (1941), No. 1, 70 pps.

This monograph pretty thoroughly covers what is known regarding the effects of electricity on hydrocarbons. Much of this knowledge is in the form of scientific investigations not yet in close touch with practice, but it has now become apparent that electricity is a powerful tool for causing hydrocarbons to react. So powerful is this tool that the full technique for controlling it completely to cause only desired reactions is not yet known. Yet enough is known to show that many useful reactions can be effected in this manner and, as this control technique is learned, more of these reactions will be used on a commercial scale.

As the main reactions of the discharges are (*1*) dehydrogenation-hydrogenation and (*2*) polymerization (condensation)-depolymerization, probably the earliest advances in controlling the reaction will be to separate these reactions so that any one can be used to the exclusion of the other. As this is done the reactions may be used to make rubber, synthetic resins and plas-



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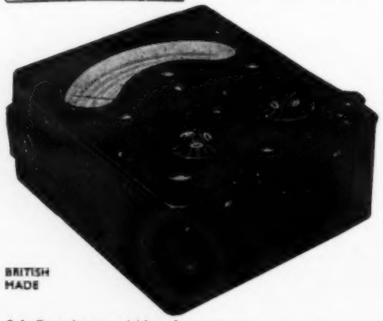

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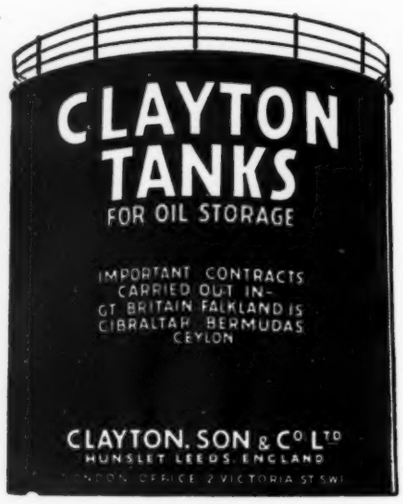

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tics, drying oils, antiknock motor fuel, and tough lubricants. Most of the principles are known and most of the reactions are known; the optimum conditions remain to be found. There is every reason to believe that in most cases the power consumption will be within economic reason when these optimum conditions are found.

The reference to "tough lubricants" brings up the process by which the product known as "Elektrion" is produced. The exact character of the raw material used has not been disclosed, but it seems to be a mineral oil rich in straight-chain olefins, or at any rate a hydrocarbon that can take up hydrogen that has been activated by the silent electric discharge. Elektrion is being or was manufactured in Belgium and the same product has been made and sold in Germany under the name "Voltoel." It is used as an additive to lubricating oils to increase the viscosity, lower the viscosity—temperature coefficient, lower the pour point and to diminish the sludge-forming tendency of the oil.

Perco Copper Sweetening—M. W. Conn, in REFINER, Vol. 10 (1941), No. 3, pp. 53-61.

In the application of copper sweetening of gasolines, copper chloride is used as an oxidation-reduction agent which in the presence of mercaptans and oxygen is reduced from the cupric to the cuprous state, and in that process transforms the mercaptans into disulfides. As developed in the Perco process the copper chloride is used in two forms. In one form of the process the sour gasoline containing a little air to supply oxygen is passed over a filter bed consisting of an absorbent carrier impregnated with a cupric chloride solution. This reagent has the remarkable characteristics of converting the mercaptans to disulphides by being reduced to cuprous chloride, which is instantaneously regenerated to cupric chloride by the air that accompanies the gasoline. The catalyst needs to be regenerated only when it has become too much contaminated with reaction water.

In the solution form of the Perco process the sour gasoline is treated with a water solution of cupric chloride, the sweetening and regenerating operations being conducted in separate zones to avoid use of air; the sweetened product is then stabilized by a sodium sulfide after-wash. The process is simpler and more versatile and requires less technical control than the doctor sweetening process.

Regenerative—Type Air Heaters for Refinery Use—O. F. Campbell and T. B. Kimball, before AMERICAN PETROLEUM INSTITUTE, 11th Mid-Year meeting, Tulsa, May, 1941.

This paper draws the attention of the oil industry to the Ljungstrom rotary air heater for use in conjunction with De Florez down-draft cracking-still furnaces. This heater operates on the continuous counterflow regenerative principle. Each revolution of a rotary furnace containing the heating surfaces produces a complete cycle of heat exchange, in which heat absorbed by metal plates from the flue-gases is given up as the rotation moves the heated plates into the path of the combustion air.

The authors set forth both the disadvantages and the advantages of the Ljungstrom regenerative air heater for the uses here considered. They consider that the few technical inconveniences in operation and maintenance considerably over-balance the disadvantages.

From operating and cost data appended to the report it appears that when installed in conjunction with a De Florez furnace involving an hourly heat absorption of 70 million Btu, the annual fuel saving was $16,320 after deducting energy costs.

BOOKS

Elements of the Petroleum Industry. Edited by E. de Golyer and others and published 1940 by American Institute of Mining and Metallurgical Engineers, New York; 21 chapters, 519 pages; non-members $5.00.

This book is the second work sponsored by the Seeley W. Mudd Memorial Fund. As set forth in the preface, it has not been designed primarily for those actively engaged in the petroleum industry; it is offered to engineers, or even to non-engineers who have an intelligent curiosity regarding the hows and whys of this most important and fascinating of all industries. It is called neither a handbook, a textbook, nor a treatise; its sponsors are content to characterize it as a readable and non-technical but authoritative picture of all phases of this amazing industry.

For producing this picture the editor has enlisted the services of 19 experts in various lines. First one and then another of these experts take the intelligent stranger in hand to show him petroleum in its different phases. The first portal is a chapter by Stewart P. Coleman on the chemistry and physics of petroleum and its derivatives. Then follow chapters which show how and where petroleum is found, how oil lands are leased; how oil rights are traded in and petroleum enterprises are promoted; and all about royalties. After the experts on these matters have had their say the technologists have their turn. J. E. Brantly starts them off with a chapter on oil well drilling machinery and practices. Others discuss the drilling, testing and completion of oil wells, (production practice, conservation, secondary methods for increasing oil recovery, pipe line transportation, marine transportation, petroleum refining, marketing, oil accounting and the natural gas industry. At the end

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we find a chapter on the economics of the petroleum industry by Joseph E. Pogue, and an introduction to the literature of oil and gas for readers whose appetites have been whetted for more information.

The volume is obviously not attractive to the casual or general reader but it is good meat for mature persons who for one sufficient reason or another feel the need of information about petroleum that is not too difficult to assimilate. A helpful index has been provided.

Warships at Work. By A. C. Hardy, with illustrations by Laurence Dunn, published 1940 by Penquin Books, Ltd., New York; 144 pages.

The publisher describes this small volume as a naval note book explaining by text and by profile some functions of the principal warship types of the world. Naturally, in the present condition of world affairs when sea power is again deciding the fates of nations, an easily assimilated manual like this is very handy in assisting readers of newspaper to visualize naval events.

Role of Clay and Other Minerals in Oil Well Drilling Fluids. By George Stern. Report of Investigations No. 3556, Bureau of Mines, Washington, D. C., February, 1941; 88 pages, and 30 illustrations.

This publication, which amounts to a small book, is addressed to a class of readers who have a large indirect interest in the use of oil well drilling muds but for whom very little has been written in the way of mud literature. These are persons in the clay and allied industries who furnish the materials from which the mud engineers compound their fluids and it is the author's object to acquaint them with the types of material required, how they are used, and what are their limitations.

In thus identifying the public he is trying to reach the author observes that to the oil industry his report will be elementary and may be considered by some to be "old stuff." Just the same, he has produced an outline from which many people in the oil industry who are not accomplished mud engineers will glean much interesting information about this very important phase of oil well drilling operations. In fact there are numerous discussions which should prove helpful to not a few men engaged in petroleum production. Aside from enlightening descriptions of the materials that come into consideration, the report contains descriptions of methods for testing muds and for controlling their properties. This gives it a definite interest for operators and especially to young mud engineers who are beginning their careers. There is appended a copious bibliography on drilling fluids containing 143 citations.

GENERAL

Cooperative Motor-Gasoline Survey, Summer of 1940. E. C. Lane, in Bureau of Mines Report of Investigations 3550 (1941).

This, the tenth in a series of reports on properties of commercial fuels made as a joint product of the Cooperative Fuel Research (C. F. R.) committee and the U. S. Bureau of Mines, shows the general results collected in the table on the following page.

When these results are compared with those of the previous survey it is found that the average figure for the octane number for the regular-price grade is 2.7 units higher for the summer of 1940 than for the previous summer, the premium-price grade is 1.1 units higher and the third grade is 0.9 units higher than for the previous summer.

Some areas present much greater drilling difficulties than others. In districts where abnormal gas, oil or water pressures tend to cause blowouts, or where caving occurs, weighted muds are essential. BAROID or COLOX can be made up to maximum weights with suitable viscosities and low water losses.

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The average vapor pressure for the regular-price gasoline is 0.1 pounds higher; for the premium-price grade, 0.2 pounds higher; and for the third-grade gasolines 0.2 pounds lower than for the summer of 1939.

The average temperatures in the distillations for the regular-, premium-price, and third-grade gasolines are lower than for the summer of 1939 at all points except the initial boiling point of the regular-price grade. Taking the 50-per cent temperature as an example, a lowering of 6°, 7°, and 5° F. is noted for the regular-price, premium-price, and third-grade gasolines, respectively.

In other words, the quality of American gasolines on the whole continues to improve with each passing year.

MOTOR-GASOLINE SURVEY, SUMMER 1940
(Summary of data of the survey)

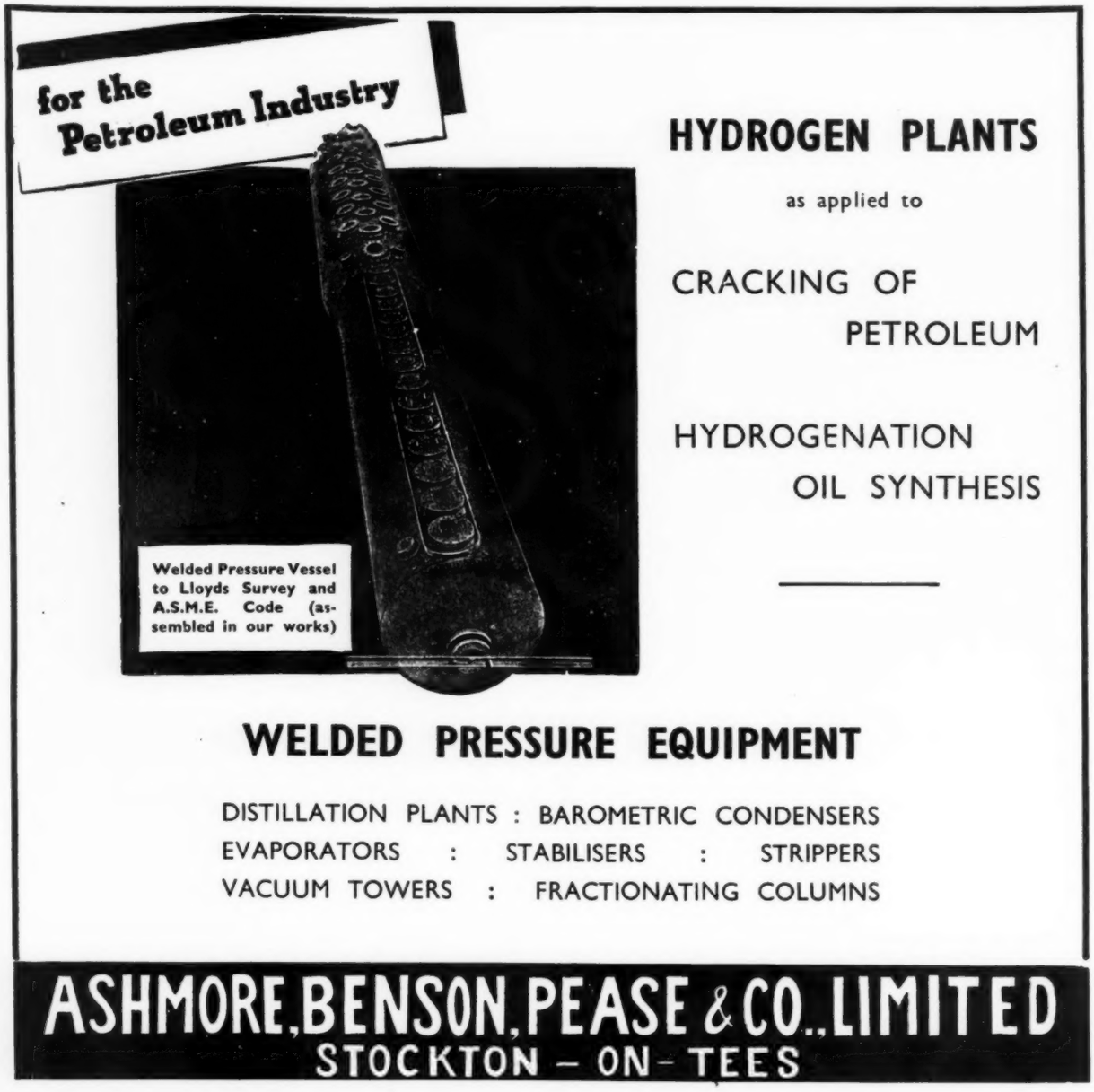
Test	Regular-price gasoline			Premium-price gasoline			Third-grade gasoline		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Gravity, degrees A. P. I.	55.8	60.3	65.9	50.7	60.6	68.7	54.6	60.9	71.6
Sulfur content, %	.02	.078	.30	.009	.055	.215	.01	.059	.35
Reid vapor pressure, lb.	4.0	7.7	9.3	5.3	7.3	9.2	5.4	7.1	10.9
A. S. T. M. octane number	62.0	74.1	78.0	74.8	79.9	83.6	46.7	64.0	76.8
Initial boiling point, °F.	89	101	130	92	103	133	89	101	115
10% recovered	127	143	177	126	145	161	127	146	167
20% recovered	148	170	186	143	168	194	147	177	204
30% recovered	166	196	224	153	189	214	166	201	240
50% recovered	205	241	266	174	228	258	192	245	289
70% recovered	254	284	312	194	268	301	216	287	331
90% recovered	318	347	380	239	328	383	284	348	399
End point	372	397	421	325	383	452	341	399	432
Distillation loss	.6	1.5	2.3	.4	1.3	2.3	.3	1.5	2.9

The Status of the Automotive Diesel. Eugene H. Fezandie before Society Automotive Engineers, Detroit meeting, January, 1941.

After tracing the history of ideas out of which the modern Diesel engine has developed the author outlines its present status and attempts to forecast its near future.

The Diesel still has certain disadvantages as compared with the automobile engine, such as higher first cost, higher maintenance cost and certain nuisances. It operates on a cheaper fuel (at present) but this advantage is at the mercy of the tax authorities, whose future attentions may alter the price relations. But the difference in fuel cost still favors the Diesel, and it is in low fuel cost rather than low cost fuel that the Diesel must eventually find its economic justification.

In conclusion the author voices the opinion that the automotive Diesel has expectation of large adoption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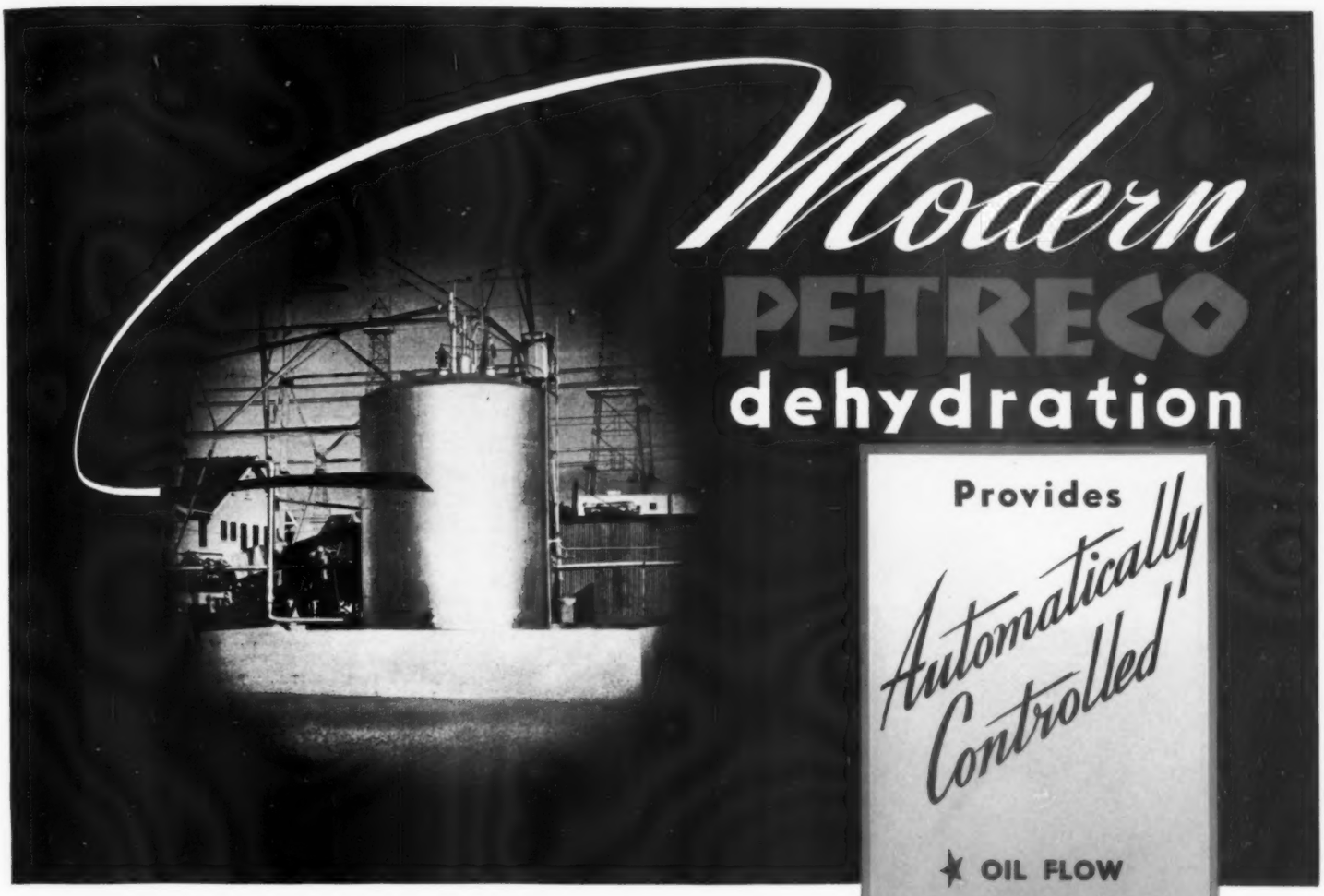

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in many fields, and that all the general classes of design will probably share in this increase, although some of them are more likely to establish themselves in fields as may require special compromises between economy, ruggedness, smoothness of performance, light weight, reliability, cost, etc.

Lower specific weights will be obtained through special materials and the reduction of overall dimensions for a given power. In the case of the open chamber type, it is expected that no large increases in speed are likely and that the best opportunity for weight reduction will be in two cycle performance. For the ante-chamber, turbulence chamber, air cell and energy cell types, the best chances to obtain weight reduction will be in supercharging and moderate speed increases. Improvement in combustion control and economy with existing fuels will be looked for from the engine designer. Better lubricants will be necessary if higher power per cubic inch of displacement is to be attained without impairing engine life. Meanwhile, the gradual reduction in cost per horsepower which is continuing should open up new fields of application where high use factor, moderate load factor, and safety are important considerations.

Significance of the 1940 CFR Road Test Technique to the Engine Builder. W. E. Drinkard, before Society of Automotive Engineers, White Sulphur Springs Meeting, June, 1941.

The new CFR road test, which makes use of a relatively new borderline knock spark advance technique, is hailed as marking a milestone in the search for a better understanding of fuel detonation characteristics in automotive engines. The new point of this test is that it takes account of variable engine speed, which previous methods of road testing did not do, much to the confusion of both fuel manufacturers and engine builders.

The automotive engine builder can readily apply this technique to two problems confronting him in the process of engine development, namely, influence of general engine design on detonation, and determination of distribution spark advance characteristics for an otherwise developed engine.

Now that the detonating characteristics of fuels in automotive fuels have been clarified, the way is opened for cooperative research that will result in the production of non-detonating fuels, meaning gasolines that will not knock at any speed.

Rubbers, Natural and Synthetic. J. W. Schade, before Institute Aeronautical Sciences, New York meeting, 1941.

This paper reviews the present status of synthetic rubbers, and defines their advantages and disadvantages in comparison with natural rubber. There are now 32 well defined varieties of synthetic rubber, together with several subvarieties. Those varieties which recently have been or are now of commercial interest in this country are of five types, as follows

1. Polymers of chloroprene: Neoprenes.
2. Reaction products of aliphatic dihalides with alkali polysulfides: Thiokols.

3. Co-polymers of butadiene with other polymerizable compounds: Perbunan, Buna S, Ameripols, Hycars, Chemigum.

4. Plasticized polymers of vinyl chloride: Koroseal.

5. Polymers of isobutylene: Vistanex.

As will be noted, several of these synthetic rubber types are made from raw material furnished by the petroleum industry, notably butadiene and isobutylene.

Investigations of the co-polymer field, though intensively pursued for some years past, have by no means covered all possible combinations. It is reasonable to expect that continued research may within a few years disclose several new synthetic rubbers made from as yet untried combinations, each possessing some desirable characteristic to a degree as yet unobtained. If this expectation is realized the usefulness of rubber-like materials, already extended by synthetics, will spread far beyond the limits imposed by the properties of materials now available.

The varieties of synthetic rubber are not only numerous but of varied properties. So far, the predominant virtue of synthetics over natural rubber is their resistance to oil and organic solvents, and it is mainly in this field that they have found their principal employment. A comparison with the natural product boils down to the following:

Superiority has been found in synthetics over natural rubber in:

a) Resistance to swelling and deterioration in contact with oils, organic solvents and water.

b) Resistance to cracking in sunlight.

c) Resistance to deterioration by heat.

d) Resistance to powerful oxidizing agents.

e) Resistance to diffusion of gases.

Rubber still exhibits superiority to all the synthetics now available in:

a) Elasticity and rebound.

b) Low heat generation through hysteresis.

c) Extensibility.

d) Resistance to stiffening at low temperatures.

In other words, natural rubber still holds first place where stretchiness and elasticity are important.

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